ASTRONOMY®

RETURN TO THE RED PLANET

Where Did All the Plutos Go?

Discover the Stars of Autumn

September 1992 U.S. $2.95
U.K. £1.75
Can. $3.50

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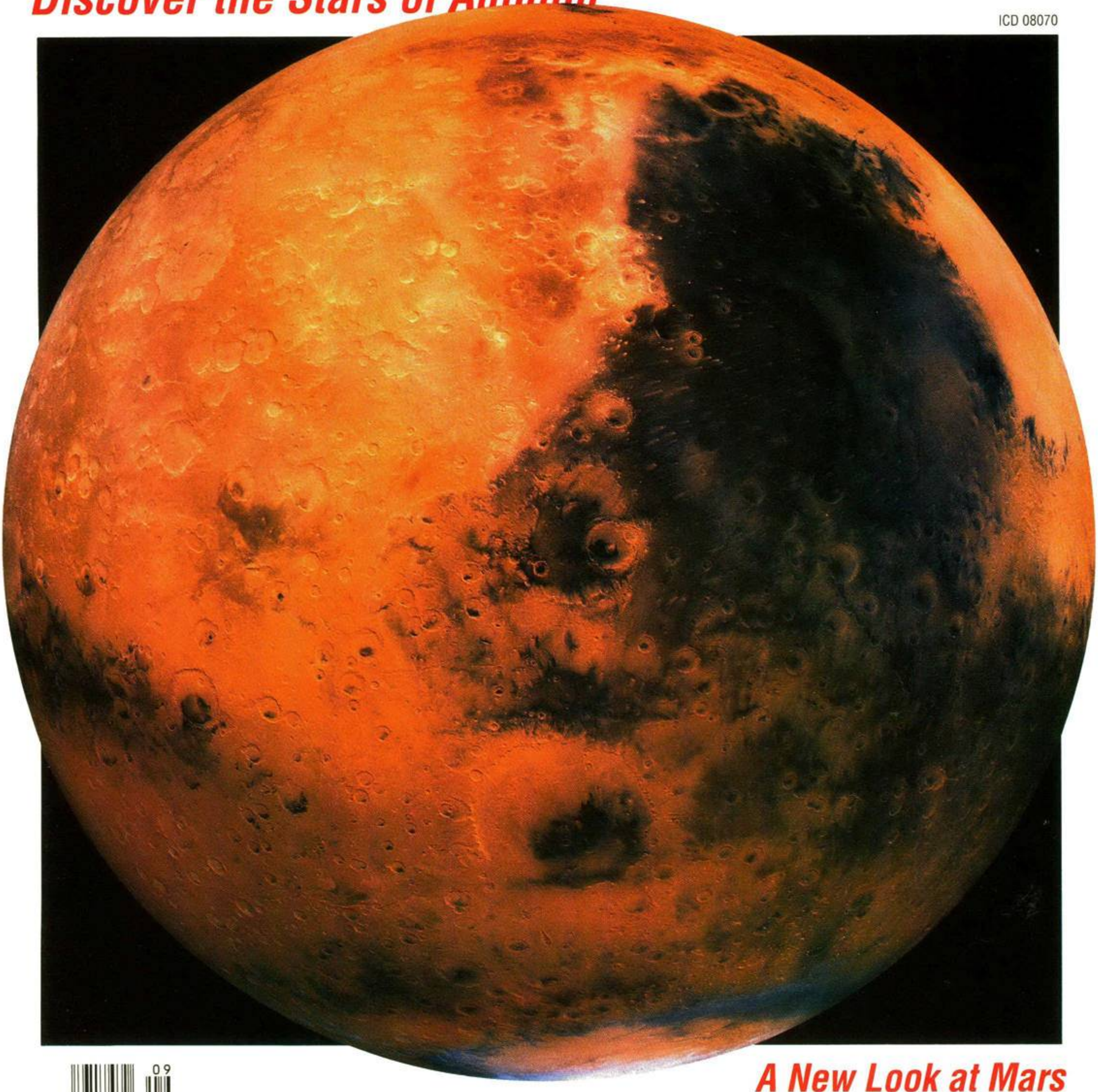


A New Look at Mars

MEADE

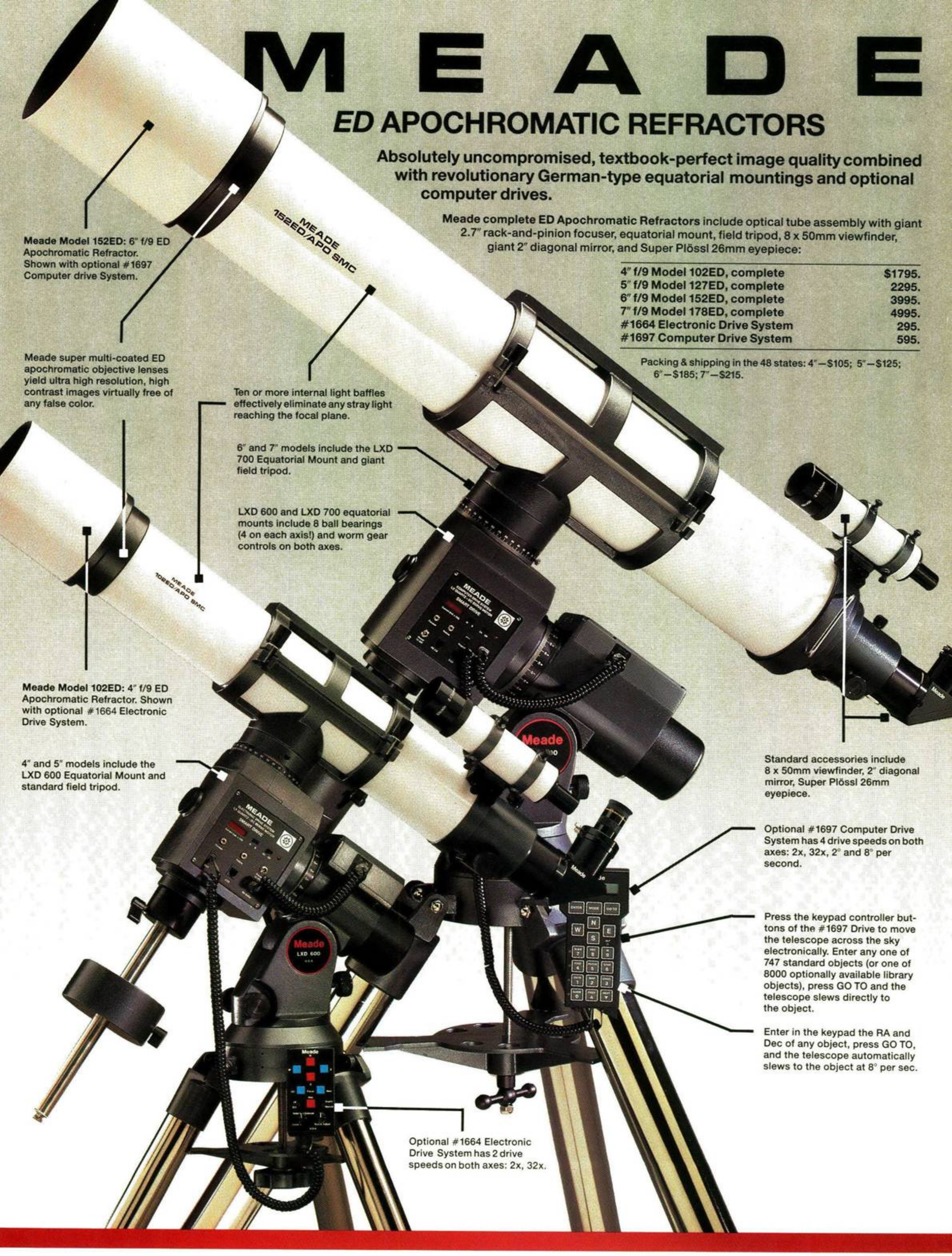
ED APOCHROMATIC REFRACTORS

Absolutely uncompromised, textbook-perfect image quality combined with revolutionary German-type equatorial mountings and optional computer drives.

Meade complete ED Apochromatic Refractors include optical tube assembly with giant 2.7″ rack-and-pinion focuser, equatorial mount, field tripod, 8 x 50mm viewfinder, giant 2″ diagonal mirror, and Super Plössl 26mm eyepiece:

4″ f/9 Model 102ED, complete	**$1795.**
5″ f/9 Model 127ED, complete	**2295.**
6″ f/9 Model 152ED, complete	**3995.**
7″ f/9 Model 178ED, complete	**4995.**
#1664 Electronic Drive System	**295.**
#1697 Computer Drive System	**595.**

Packing & shipping in the 48 states: 4″—$105; 5″—$125; 6″—$185; 7″—$215.



Meade Model 152ED: 6″ f/9 ED Apochromatic Refractor. Shown with optional #1697 Computer drive System.

Meade super multi-coated ED apochromatic objective lenses yield ultra high resolution, high contrast images virtually free of any false color.

Ten or more internal light baffles effectively eliminate any stray light reaching the focal plane.

6″ and 7″ models include the LXD 700 Equatorial Mount and giant field tripod.

LXD 600 and LXD 700 equatorial mounts include 8 ball bearings (4 on each axis!) and worm gear controls on both axes.

Meade Model 102ED: 4″ f/9 ED Apochromatic Refractor. Shown with optional #1664 Electronic Drive System.

4″ and 5″ models include the LXD 600 Equatorial Mount and standard field tripod.

Standard accessories include 8 x 50mm viewfinder, 2″ diagonal mirror, Super Plössl 26mm eyepiece.

Optional #1697 Computer Drive System has 4 drive speeds on both axes: 2x, 32x, 2° and 8° per second.

Press the keypad controller buttons of the #1697 Drive to move the telescope across the sky electronically. Enter any one of 747 standard objects (or one of 8000 optionally available library objects), press GO TO and the telescope slews directly to the object.

Enter in the keypad the RA and Dec of any object, press GO TO, and the telescope automatically slews to the object at 8° per sec.

Optional #1664 Electronic Drive System has 2 drive speeds on both axes: 2x, 32x.

8″ Model 2080A: $1099.*
10″ Model 2120A: $1379.*

4″ Model 2045D: $599.*

4″ Model 2045D: the Ultraportable Meade SCT

For the beginning astronomer the lightweight and easy-to-use Meade 2045D packs a powerful potential for serious observing. As a second telescope for the advanced amateur, the 2045D permits wide-ranging observations in locations inaccessible or inconvenient to larger instruments. Each telescope includes optics manufactured to the same high performance standards as larger Meade models. The DC drive system operates from a micro battery pack for convenient field use. Full accessorization is available for virtually any field application.

Meade Standard Series 8″ and 10″ SCT's: advanced technology at economical pricing levels.

No other comparably-priced Schmidt-Cassegrains offer the optical and mechanical features of the Meade Standard Series:

■ **Optics:** The World's most recommended and largest-selling Schmidt-Cassegrain optics, warranted to be the finest available from any manufacturer. Razor-sharp imaging through both 8″ and 10″ models. Standard Series 8″ and 10″ SC optics are the exact same as used on Meade LX200 models.

■ **Mountings:** Highly stable, low vibration fork mountings designed for advanced applications such as long-exposure astrophotography, mountings that can carry more than *twice the payload* of competing small German-type mounts.

■ **Standard-Equipment Motor Drive System:** Not an add-on, but *a built-in 5.75″ worm gear drive that is the most accurate available on any SCT in this price range.*

■ **Variable-Height All-Metal Field Tripods:** The finest tripods yet developed for SC telescopes, the ultimate in rigidity and low-damping time.

■ **Optional Systems:** Unlike competing German-mounted SCT's with small worm gears, Meade Standard Series SCT's permit almost unlimited growth potential—use the **#46 Dual-Axis Drive Corrector** for deep-space photography with the **Off-Axis Guider** system; **#929 2″ Diagonal** with **2″ Super Wide Angle** eyepieces for breathtaking wide-field observing; and much more. ***See the Meade catalog for details!***

Specifications: Model 2045D—Complete with 4″ f/10 Schmidt-Cassegrain tube assembly with super multi-coated optics; fork mount with setting circles, manual slow-motion controls, and locks on both axes; 12-volt DC pulse motor, spur gear drive system; AA battery pack (batteries are not included); tabletop tripod system; eyepiece holder/diagonal prism; coated MA 25mm (40X) eyepiece (1.25″); 5 x 24mm viewfinder. . . . . **$599.**

Packing and shipping in the 48 states . . . . **$40.**

Specifications: 8″ Model 2080A—Complete with 8″ f/10 Schmidt-Cassegrain optical tube assembly; fork mount with setting circles, manual slow-motion controls and locks on both axes; 5.75″ worm gear motor drive system (115v./60Hz); eyepiece-holder (1.25″); diagonal prism; coated MA 25mm eyepiece (1.25″); 6 x 30mm viewfinder; equatorial wedge; variable-height all-metal field tripod. . . . . **$1099.**

Model 2080B—Identical to Model 2080A, but in addition with Super Multi-Coated optics. . . . . **$1149.**

Packing & shipping on either 8″ model in the 48 states: . **$95.**

Specifications: 10″ Model 2120A—Complete with 10″ f/10 Schmidt-Cassegrain optical tube assembly; fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75″ worm gear motor drive system (115v/60Hz); eyepiece holder (1.25″); diagonal prism; coated MA 25mm eyepiece (1.25″); 8 x 50mm viewfinder; equatorial wedge; variable-height all-metal field tripod. . . . . **$1379.**

Model 2120B—Identical to Model 2120A, but in addition with Super Multi-Coated optics. . . . . **$1449.**

Packing & shipping on either 10″ model in the 48 states: **$125.**

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☐ **For further information on Meade ED Apochromatic or Schmidt-Cassegrain telescopes, visit one of the hundreds of Meade dealer showroom locations throughout the USA; or contact one of the authorized mail-order dealers at left. Or call Meade Instruments toll-free at 1-800-854-7485 (in California 714-556-2291).**

☐ *All prices shown are suggested USA mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable.

☐ The all-new **1992 Meade General Catalog**—$3.00 postpaid—is available from any authorized Meade dealer or directly from Meade Instruments.

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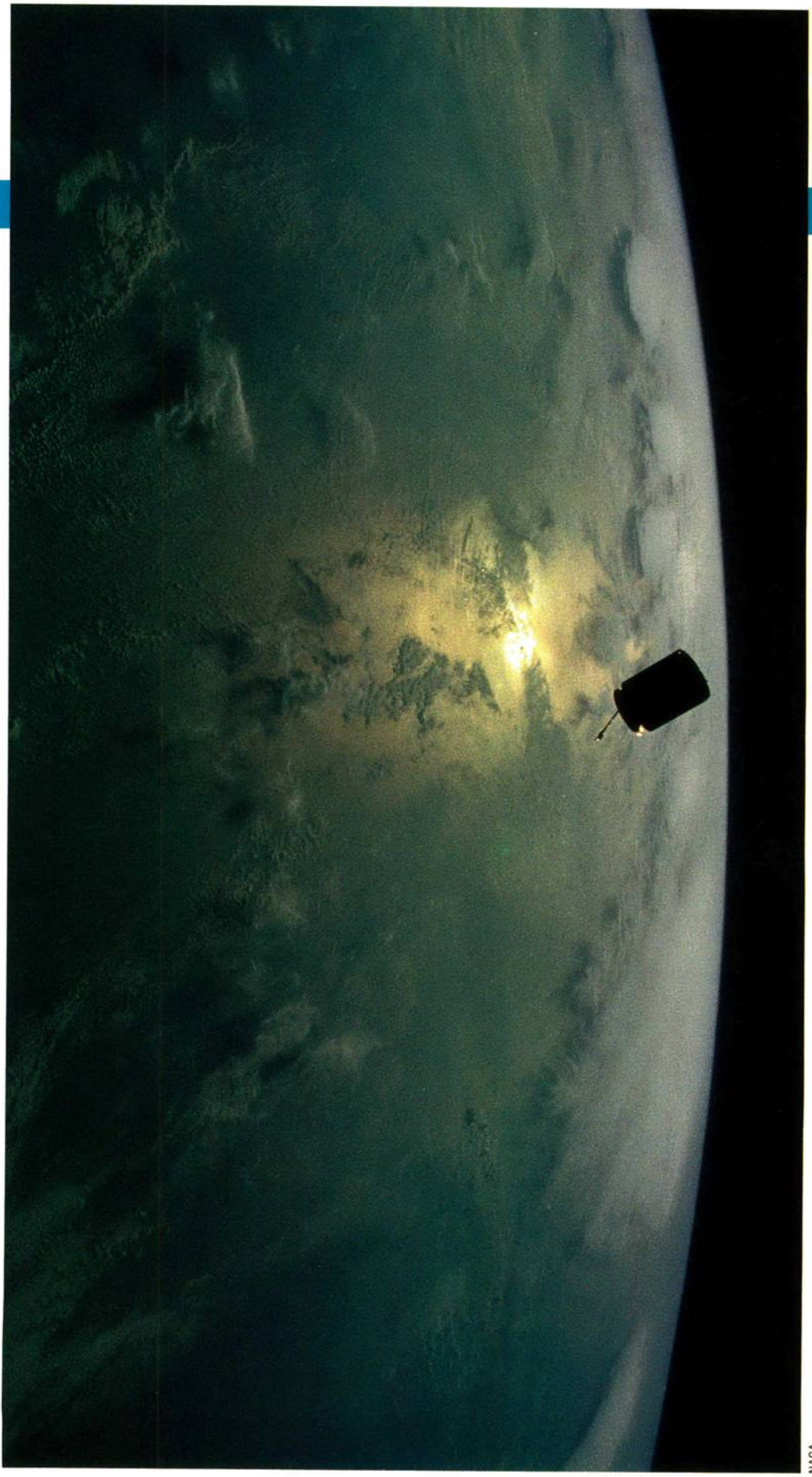
ON THE COVER: Mars becomes the focus of attention in September as the Mars Observer spacecraft begins its year-long journey to the Red Planet. This mosaic of 100 Viking orbiter images taken in 1980 shows the Syrtis Major hemisphere of Mars as you would see it from 1,200 miles above the surface. The view extends about 1,000 miles north and south of the image center (latitude 2° S, longitude 305°). See story on page 28. Photo courtesy U. S. Geological Survey, Flagstaff, Arizona.



NASA

FLOATING HIGH ABOVE EARTH, the stranded Intelsat VI satellite beckons the astronauts on the shuttle Endeavour. Last May, the crew grabbed the satellite, attached a new rocket motor to its base, and released it into space. For more photos from this headline-making mission, turn to page 26.

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The Audit Bureau

Behind the Scenes

RETURNING TO THE RED PLANET

If all goes well, the Mars Observer spacecraft will depart Earth this month for a year-long trip to Mars. It will be the first U.S. spacecraft to visit the Red Planet since the Viking project of the mid-1970s, and the first craft from any nation since the ill-fated Soviet Phobos mission four years ago.

These missions, like all the others of the past thirty years, have contributed to building an image of the solar system in the public mind and in popular culture. Jupiter? We've learned that it's impressively big and colorful. Saturn? Those rings are awesome! And Venus? It's the lava-smothered planet from hell.

But Mars is different. It isn't so easily pigeonholed. Thanks to Percival Lowell, Mars carved a niche in the popular mind long before space probes could depict its reality. As a result, the Mars we carry around in our imagination has never completely escaped Lowell's romantic vision of a dying world. The real Mars turned out to be dead enough all right. But among its wonders, astronomers have found places — canyons and playas — where water once flowed and pooled, perhaps even in oceanic volumes. These landforms point toward an early wet climate that was far more hospitable for life than today's. And some scientists think it's at least possible that Mars has fossils of long-extinct life-forms that thrived until the changing of geological seasons made conditions too difficult for them.

It's a long jump from the backyard observer's Mars to that depicted by space probes — and a vastly bigger jump to searching for Martian fossils, a task for which no mission has yet been designed let alone built. The backyard observer sees Mars as a soft, salmon-hued disk that floats in inky blackness. Capped with white and displaying darkish markings, Mars slowly turns before our gaze like a kind of movie screen onto which we project our understanding.

Viking and its Mariner forerunners turned that blurry tantalizing image into a rock-strewn desert world with as much sheer geography as all the land areas of Earth put together. Like a photo print swimming into view in the developer tray, Mars' landscape has grown in detail and interest with each new mission.

Now it's Mars Observer's turn (see page 28). This time, the Red Planet will be a mixture of the familiar and the strange. What the coming "new" Mars will look like is unknown, but surely it will sharpen old perceptions while offering surprises of its own. And by a delightful twist of fate born in the orbital mathematics of spaceflight, Mars Observer stands poised at Cape Canaveral precisely as thousands of backyard astronomers are also preparing to return to Mars — by readying their telescopes for the planet's opposition coming early in January.

Sincerely,

Robert Burnham
Editor

ASTRONOMY

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Letters

Reflection on Time Travel

Barry Parker's article "Tunnels through Time" (June 1992) was a spectacular piece of work, fascinating and informative. Parker's suggestions about time travel using wormholes were absorbing to read. Yet don't we already have time travel of the best kind? All we need to do is peer through a telescope at a distant galaxy and we can travel back in time by millions of years. — *Louise Ireland-Frey, Cedaredge, Colorado*

Futures of Astronomy and Space Linked

Looking at how government money has been spent over the past 30 years, it's clear that the fortunes of science and space flight rise and fall together. This suggests that the best way to weather budgetary storms like the current one is for scientists and manned space flight advocates to become allies. But right now the question of which area to fund is being debated more and more as decisions about where money will go rapidly approach. Should the government fund large projects like the Superconducting Supercollider or the Space Station or should it fund a greater number of smaller projects founded on basic research?

Over the past 30 years, we've seen only one year in which budgeting for science decreased while the space flight budget increased: the year following the Challenger disaster. Since 1962, the science budget has decreased in only four years; during three of those four years, the space flight budget also decreased.

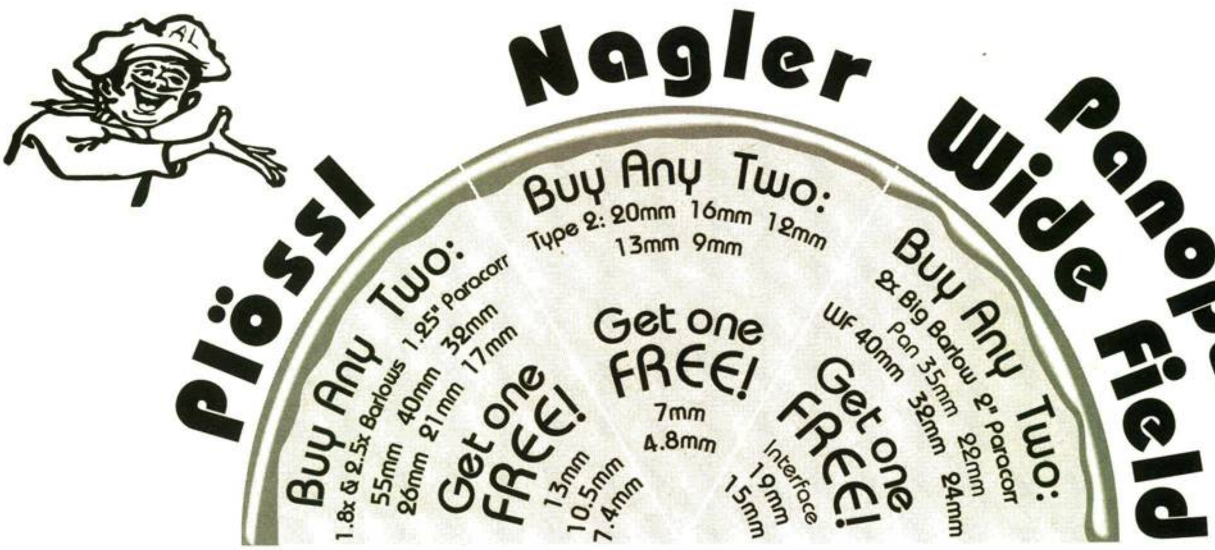
Critics say Space Station Freedom threatens to rob money from science projects. But in the time since Freedom contracts were first awarded, science budgets have grown by 61 percent! The historical trend suggests that supporters of science and supporters of manned space flight should support both. Their mutual interest is to maintain a balanced program of manned space flight and strong science. — *Harvey J. Willenberg, Space Station Freedom Program, Boeing Defense and Space Group, Seattle, Washington*

The Low Cost of Astronomy

I don't get all of the discussion about the high cost of becoming an amateur astronomer reflected in Bruce Swayze's letter (April 1992). I have just finished building a 6-inch Newtonian reflector out of PVC pipe and a mirror blank. It was an exciting job and something I can be proud of doing myself. I am waiting to get the mirror aluminized and I'll be all ready to observe. The entire project

Nagler • Panoptic • Wide Field • Plössl

FREE!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Buy Any Two:
1.8x & 2.5x Barlows 1.25" Paracorr
55mm 40mm 32mm
26mm 21mm 17mm
Get one FREE!
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Patented Tele Vue eyepiece designs started a "space-walk" revolution. Bringing you far more field, sharpness and contrast than ever before. And still today, genuine Tele Vue Plössl, Wide Field, Panoptic and Nagler eyepieces deliver greater apparent field and edge sharpness than any other brand. All models have rubber eyeguards and each eyepiece is full field inspected before it leaves our hands for yours.

The more eyepieces you order, the more FREE items you receive. So, get your friends together and pool your orders for best selection. This offer ends September 30, 1992. Applies to merchandise in-stock at time of order. Take a Tele Vue out tonight and discover the eyepieces designed for a lifetime of viewing enjoyment.

"After seeing the recent ad with all the letters touting (competitive) eyepieces, I had to respond. I consider myself a very critical observer. Using a 10" f/5.6, I found the Tele Vue 40mm Wide Field superior to the (competitor) in sharpness, both center and edge. I have used very expensive and inexpensive eyepieces. I have found none optically superior to Tele Vue for astronomical purposes." - Kenneth Drake, Houston Astronomical Society

"Our observatory has a 16" f/5, and I recently tested my 26mm and 17mm Tele Vue against a new (5-element) competitive "Plössl". The Tele Vue eyepieces were much sharper, with more contrast. Sharpness at the edge of the field was far superior." - Steven Sherrod, TX

"Your eyepiece (20mm Nagler) has given me the most pleasant case of insomnia imaginable." - Tom Lorenzin, Author of 1000 + Guide to Deep Sky Observing

Tele Vue

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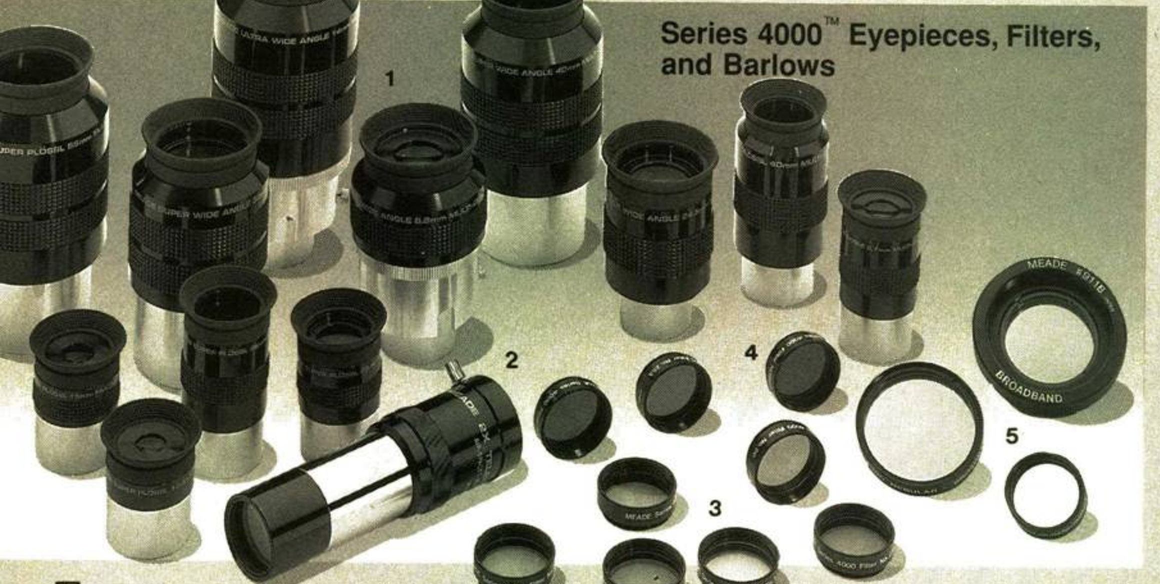
Series 4000™ Eyepieces, Filters, and Barlows

1 The World's finest telescope eyepieces now include rubber grips and soft rubber eyeguards for an even better observing experience! All eyeguards fold down for eyeglass wearers—a feature not available on competing brands. Best of all, **Meade Series 4000's are guaranteed to deliver more field, more contrast, and more image sharpness than any other brand at any price, or your money back.*** For splitting the closest doubles, revealing tenuous, faint nebulosity in deep-space, or studying hairline lunar and planetary detail, Meade multi-coated Series 4000's are the oculars that serious observers insist upon. ***"Clearly the best."***

Super Plössls (5-elements; 1.25"; 52°):
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32mm(52°); 40mm(44°); each **99.95** (2.49)
56mm (52°, 2") **219.95** (3.18)

Super Wide Angles (6-elements; 1.25"; 67°):
13.8mm: **129.95** (2.49) 18mm: **139.95** (2.49)
24.5mm: **159.95** (2.49) 32mm(2"): **229.95** (3.18)
40mm(2"): **279.95** (3.18)

Ultra Wide Angles (8-elements, 1.25"; 84°):
4.7mm: **147.95** (2.49) 6.7mm: **187.95** (2.49)
8.8mm(1.25"/2"): **219.95** (3.18)
14mm(1.25"/2"): **249.95** (3.18)

*at participating dealers; see catalog for details.

2 **#140: Series 4000 2x Apochromatic Barlow Lens** (1.25")--The original Meade 3-element, air-spaced, multi-coated design. Absolutely unmatched in image resolution and color correction. 28mm dia. lens (26mm clear aperture). **$69.95** (2.49)

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#8 Lt. Yellow; #11 Yellow-Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue.
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Set #1—4 filters: #12 Yellow, #23A Lt.Red, #58 Green, #80A Blue **$42.95** (2.49)

Set #2—4 filters: #11 Yellow-Green, #25A Red, #47 Violet, #82A Lt. Blue **$42.95** (2.49)

Set #3—4 filters: #8 Lt. Yellow, #21 Orange, #38A Dark Blue, #56 Lt. Green . **$42.95** (2.49)

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#908N (1.25")—Threads into virtually all 1.25" eyepieces; 26mm clear aperture. **89.95** (1.79)

#910N—Threads into all Meade 2" eyepieces and most others; 44mm dia. **119.95** (2.49)

#911N--Threads on to the rear cell of Schmidt-Cassegrain telescopes. **109.95** (2.49)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Internal batteries included. Multi-coated optics. Bullseye reticle. 1.25"
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.965": $24.95 (2.49) **1.25": $29.95** (2.49)

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Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-Mount for your camera.
$39.95 (2.49)

Tele-Extenders

For Eyepiece-Projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Use with T-Mount for your camera.

Basic Tele-Extender: *(above)* Fixed projection power; use with eyepiece for lunar and planetary photos. **$26.95** (2.49)

Variable Tele-Extender: Sliding cell, with lock, permits wide range of projection magnifications with the same eyepiece.
$36.95 (2.49)

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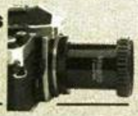

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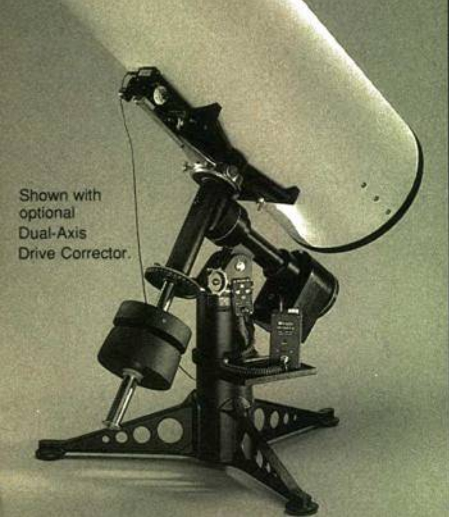

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MEADE LX100 SCHMIDT-CASSEGRAINS

Observers not requiring the sophistication of the LX200 electronics may wish to consider an 8" or 10" LX100 model SCT instead. Meade LX100's include the exact same heavy-duty fork mounts of their LX200 counterparts, but with a microfine declination tangent arm control in place of the LX200's motorized worm gear, and with a 2-speed drive in place of the LX200's 4-speed drive; optical tubes and coatings are identical. Standard LX100 features include:

■ Handheld Electronic Command Center—With 2-speed operation, **2x** for photo-guiding and **32x** for image centering and microslewing in the main telescope. (With the optional DC-servo declination motor installed, these speeds are operational on both telescope axes.)

■ Permanently programmable (PPEC) Smart Drive, as described above.

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Specifications: 8" and 10" LX200's—Each complete telescope includes: 8" or 10" SC optical tube assembly (specify f/6.3 or f/10) with super multi-coatings; heavy-duty fork mount, with 4" polar ball bearing, dual-axis 5.75" worm-gears, and multi-function power panel display on the drive base; manual slow-motion controls on both axes; handheld keypad Electronic Command Center, with digital readout display, PPEC Smart Drive, four-speed drive control on both axes, GO TO controller, and 747-object software library; 25 ft. power cords for telescope operation from either 12 v. DC auto cigarette lighter plug or 115v.AC; 8 x 50mm viewfinder with crosshairs; diagonal prism (1.25"); Series 4000 Super Plössl 26mm eyepiece; variable-height field tripod; new deluxe die-cut-foam-fitted carrying case; complete operating instructions.

Specifications: 8" and 10" LX100's—Each complete telescope includes 8" or 10" SC optical tube assembly (specify f/6.3 or f/10) with super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, 5.75" RA worm gear, and multi-function power panel display on the drive base; manual slow-motion controls on both axes; handheld pushbutton Electronic Command Center with PPEC Smart Drive and 2-speed drive control; 25 ft. power cords for telescope operation from either 12v. DC auto cigarette lighter plug or from 115v. AC; viewfinder: 6 x 30mm (8") or 8 x 50mm (10"); diagonal prism (1.25"); Series 4000 Plössl 26mm eyepiece; variable-height field tripod; equatorial wedge (8") or Superwedge (10"); new deluxe die-cut-foam-fitted carrying case; complete operating instructions.

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10" models	**145.**

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■ For dealer or catalog information see the Meade **ED Apochromatic Refractor** ad in this issue.

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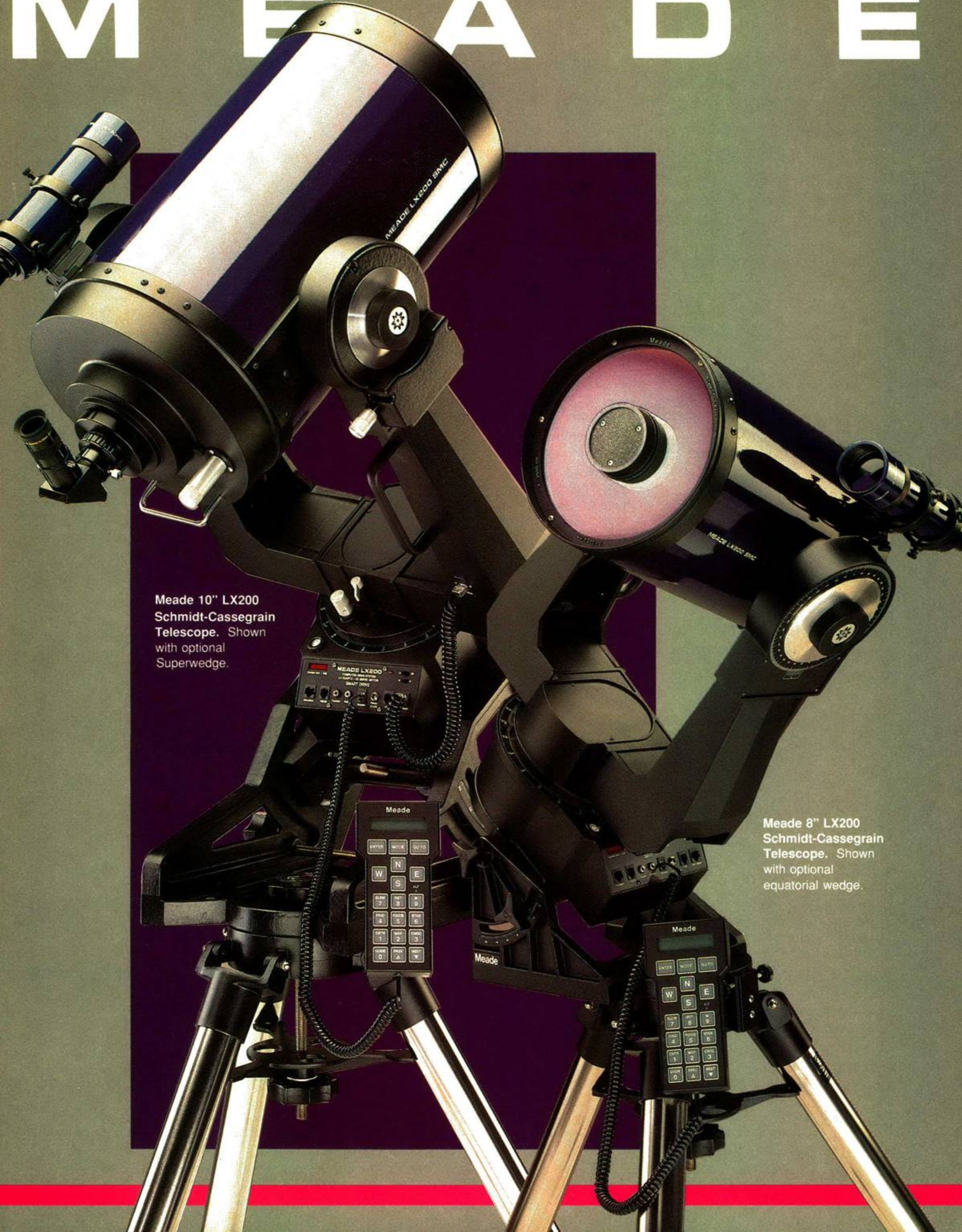
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cost about $150. — *Chris Huston, Tomahawk, Wisconsin*

I enjoyed the response to Richard Hill's Viewpoints article in the April letters column. Hill is correct in saying that astronomy has become a rich person's hobby. The majority of amateur astronomers I know are doctors, lawyers, engineers, or other highly paid professionals, and the high cost of equipment definitely has stunted the interest of many newcomers. Yet other issues exist. I have friends in other countries who do not have access to fancy equipment, and they routinely make amazing observations with simple equipment. It doesn't need to cost a fortune to get started in this great hobby. More important than the equipment issue is the lack of help given to many newcomers when they visit astronomy clubs. They need encouragement, advice, and guidance — not a show of impressive knowledge. As Shakespeare wrote, "The fault lies not in our stars, but in ourselves." — *Gordon Bond, Middlesex, New Jersey*

Revere Rides On

Darrel Hoff and I enjoyed seeing the article we contributed on the astronomical circumstances during Paul Revere's famous ride (Viewpoints, April 1992). I would like to add a few more points about the time of high tide in Boston harbor on that fateful night.

When computing the tidal height at Boston on the night of April 18/19, 1775, one of us (JV) placed too much confidence in the routine and did not make allowance for the Gregorian correction. Thus, the tide predicted for that night was in fact for the night of April 16/17. In fact, high tide occurred on the night of Paul Revere's ride shortly before 2:00 a.m. on the 19th. Darrel and I still feel that the unusually high tide that forced British troops to wade ashore played a part in the failure of the expedition against the Patriots. — *Jacques Vialle, Laboratoire d'Astronomie, Université de Paris, La Rochelle, France*

SUNSEARCH Network Reorganizes

SUNSEARCH, founded by Steve Lucas of Midlothian, Illinois, is an organization of amateur astronomers dedicated to searching for supernovae in galaxies. Steve's direction of the group has been heroic, but he now finds that he does not have the time to devote to running the network. To revitalize the group and keep it an active part of the astronomical community, several members will take over Steve's duties. The undersigned, a codiscoverer of Supernova 1991T in NGC 4527, will serve as the group's director and editor. Two other officers will help with various duties: James T. Bryan, Jr., discoverer of Supernova 1980K in NGC 6946, and Dana Patchick, discoverer of Supernova 1987L in NGC 2336. Jenny Worsnopp will continue her role of collecting observations, and Steve will continue with sage advice.

The organization will now publish its newsletter, *Starburst,* quarterly, and we encourage all backyard observers to find out more about our organization. Please write me for more information. You, too, may one day discover a supernova! — *Wayne Johnson, 2630 Raven Circle, Corona, California 91720*

Pushing to the Limit

Quasars are infrequently observed by amateur astronomers. But a group of us from the Houston Astronomical Society challenged ourselves to observe the most distant quasar we could locate at the 1992 Texas Star Party. Using a 24-inch telescope and a detailed finder chart, Barbara Wilson, Brian Skiff from Lowell Observatory, Steve O'Meara of *Sky & Telescope,* galaxy expert Harold Corwin, and I all spotted 1331+170, more commonly known as Molongo 3. The quasar, which lies in Coma Berenices, glows at magnitude 16 and appears like a faint star. Yet its redshift of 2.081 suggests it is nearly 9 billion light-years distant. Have other amateurs observed such a distant quasar? — *Larry Mitchell, Houston Astronomical Society, Houston, Texas*

A Magazine for Home Observatories

Observatory Techniques (ISSN 1060-880X), a quarterly magazine for backyard astronomers, has just been launched. The first issue contains articles about astronomy and computer techniques, including video imaging, how to build a dome, and astronomy software and equipment reviews. The annual subscription rate is $16. For more information, contact the undersigned. — *Mike Otis, 1710 SE 16th Avenue, Aberdeen, South Dakota 57401* ☐

ASTRONOMY welcomes comments and additional information on articles and astronomy in general. Send your letters to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length or clarity.

LOOKBACK TIME

by Lee Park

There comes a time, about in the middle of your life, when you begin to suspect that your possibilities aren't unlimited. The future you've always talked about has not only arrived, it now seems to be slipping behind you. You wonder how your life got to be as complicated as it is, and why. And you're sure — absolutely sure — that there's nothing ahead of you but a nursing home.

I walked hesitantly into a local telescope store, thinking perhaps I could rekindle one of the passions of my youth. As I began sizing up the latest models, a man's voice startled me: *"May I help you?"*

I looked up at the huge bearded man and knew instantly that he was the owner of the store. I also knew that saying "yes" would get me in some trouble. "Well, ummm, maybe," I stammered. I immediately launched into my story: "You know, when I was a kid I really liked astronomy, even had a small telescope, but then . . ."

"Do you know how many times a day I hear that?" thundered the owner. *"It's always the same story. I know, you grew up and went off to do important things and now, years later, you're depressed about your life and you expect me to pick up the pieces."*

Oh great. I've picked a telescope dealer who's got an attitude and is having a midlife crisis of his own. A psychologist friend had gently counseled me that the way out of midlife blues was to look for things in your past that you loved doing and start doing them again. Well here I am, in an astronomy store trying to find my lost passion and recover the direction in my life. And I'm getting yelled at.

"It was probably a 3-inch reflector with a lousy mount, lousy eyepieces, and a cardboard Barlow."

Why did I stop doing astronomy in junior high? I don't know, but other things seemed more important and serious — sports, girls, cars, college, to name a few. I had to get on with life.

"You say you're a photographer? I suppose you'll want to take pictures too."

I bought a 4-inch Schmidt-Cassegrain. After all, I thought, I'm not looking for an all-consuming avocation, just an interesting and soothing diversion. I took it out and pointed it at the Moon — and my heart leaped with excitement at the image. I looked at Jupiter. I looked at double stars. I enjoyed that scope; it brought me a measure of real peace.

And then a funny thing started to happen. I became dissatisfied. I wanted better eyepieces. I wanted a bigger aperture. I wanted a better mount. I wanted to take pictures. I wanted to get serious.

"You want to what? I thought you wanted to keep this simple. Do you have any idea what you're getting into?"

This time I bought a 10-inch equatorially mounted Newtonian reflector. A serious instrument for a serious amateur. And excellent eyepieces. By now, I subscribed to several magazines and bought the right books. I joined a local club. I knew all the jargon. I ate, breathed, and slept astronomy. But something else happened. I wasn't observing much. The tube was big and a real struggle to cart around. I hated the counterweights for the mount. I didn't like fussing with collimation. I felt guilty when I didn't observe and was secretly relieved when it was cloudy. I pored over the catalogs again — maybe hooking it up to a computer would do it, or maybe a CCD camera.

"Didn't I warn you about this? Why do all of you have to go through this whole deal? Why won't anyone listen to me?"

Suddenly I found my pursuit of astronomy mirroring life. Astronomy was complicating my life rather than helping to clarify it. I had lost my way. Again.

"Simplify, simplify, simplify."

I sold my reflector. The curmudgeon let me try various telescopes on weekends. I bought an excellent 5-inch refractor and put it on a Dobsonian mount. I forgot about photography. I forgot about deep-sky objects. I looked at the Moon. I looked at planets. And slowly, something happened. I lost my consumer mania. I lost "observer's guilt." I gained some peace. I was enjoying myself again.

I've read that telescopes function as time machines — the farther you look out in space, the farther you look back in time. Indeed, my telescope can do that.

[continued on page 16]

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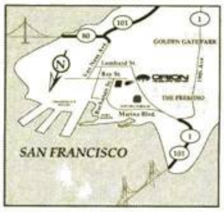

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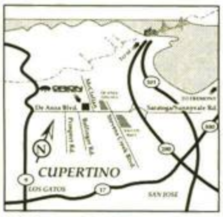

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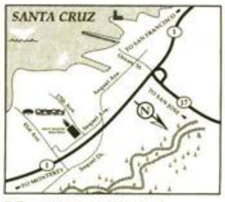

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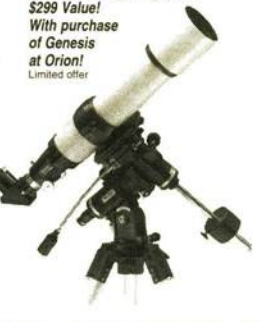

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Orion® 10x70 FMC Giants

The standard for hand-holdable astronomy binoculars. Fully Multi-Coated, 33% lighter—weighs only 58 oz.—yet the same brightness and 7mm exit pupil as our 11x80 MC model. Superior 'BCF' body design. Includes: soft rubber eyecaps, tripod mounting adapter, durable hard carrying case, lens caps and straps.

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11x80 MC- Brightest, widest field available. Ideal for deep-space observation under dark skies. Hand-holdable.
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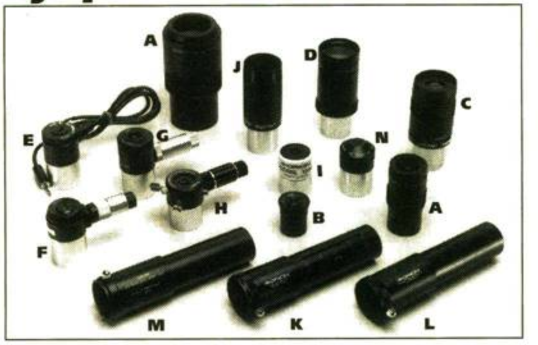

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40mm 2" UltraScan Eyepiece
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B Explorer .965" Eyepieces

Fine quality Multi-Coated eyepieces.

.965" Orthoscopic 5mm #8580, 7mm #8581, 9mm #8582, 12.5mm #8583 **$42.95 ea.** (2.98)

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.965" Achromatic Huygenian 40mm #8586
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C UltraZoom™ 7–21mm

The finest zoom you can buy for your 1.25" telescope. For astronomy or terrestrial observing. 65°-35° field. Fully coated. #8556 **$139** (3.67)

D Superb Ultrascopic™ Eyepieces

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35mm #8560 **$89.95** (3.45)

High Power 7-element *—Long Eye Relief*
5mm #8574, 3.8mm #8576
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E 12mm Kellner Illuminated Reticle Eyepiece

12mm Kellner eyepiece with cable plugs into power panel drive bases, and most drive correctors with illuminated reticle output for polar alignment and guiding. #8482 **$69.95** (3.45)

F 9mm Illuminated Reticle

9mm Orthoscopic eyepiece with wireless adjustable brightness illuminator. Bull's-eye within three concentric circles helps measure limits of acceptable guiding error.
#8488 **$119** (3.67)

G Orion® 12.5mm Plössl Illuminated Reticle Eyepiece

This new 12.5mm 4-element Plössl offers unprecedented eye relief and observing comfort during long astrophoto exposures. The battery operated integral illuminator has fully adjustable brightness. Features double crossline reticle.
#8484 **$99** (3.45)

H 6mm Illuminated Reticle

6mm Orthoscopic design for high power guiding, unique X-Y adjustable reticle positioning for easy guide star alignment. Wireless LED illuminator has adjustable brightness. #8487 **$129** (3.67)

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Orion Multi-Coated Plössl eyepieces are fine performers at an amazingly low price. Precision 4-element Plössl lens elements mounted in sturdy aluminum barrels. Available in 12mm, 18mm, or 25mm focal lengths, with 1.25" barrels. Buy all three for less than some single eyepieces!
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J MegaVista™ Wide Angle

Incredible Fully Multi-Coated high-transmission 7-element eyepieces with integral rubber eyeguard and long eye relief.

10.5mm—An incredible 67° field for outstanding planetary or deep space performance.
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16.8mm—Outstanding high-contrast eyepiece with stunning 70° field ideal for deep space.
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K VariPower™ 2-3x Barlow

Our best barlow fills the gaps in your eyepiece collection. Internal lens cell slides easily to adjust magnification. Quality optics provide excellent sharpness, contrast and brightness. Works with 1.25" diameter eyepieces and right-angle diagonals.
#8748 **$59.95** (3.45)

L Ultrascopic 3-Element Barlow

Fully Multi-Coated 3-Element Barlow lens provides superior imaging with precise color correction at three wavelengths. For maximum light transmission and highest contrast, we have used the finest quality multi-coating on each air to glass surface. 1.25" diameter. #8750 **$54.95** (3.45)

M Fully-Baffled Barlow Lens

Fully internally opaqued and baffled to block stray light for noticeably higher contrast. Large 27mm multi-coated 2-element lens provides 2x magnification with any 1.25" eyepiece.
#8746 **$44.95** (2.98)

N Explorer 1.25" Eyepieces

Guaranteed high-performance, Multi-Coated parfocal eyepieces with great performance. Each carefully selected series has been chosen to provide a sensible progression of magnifications. Threaded for filters. Internally blackened to prevent stray light reflections.

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Orthoscopic Eyepieces*—Excellent Performance*
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Filters

Color Eyepiece Filters

Highest quality precision-ground optical glass. Fully anti-reflective coated. Piggyback precision aluminum cells. Solar system observations are dramatically improved by Orion colored filters. Thread one into the barrel of any standard eyepiece. Can also be threaded directly into a universal camera adapter.

.965" Basic Set of 4 Filters Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.
#5510 **$34.95 set** (2.98)

1.25" Basic Set of 4 Filters #5514
Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.

1.25" Expansion Set of 4 Filters #5516
Includes #21 Orange, #47 Violet, #11 Yellow-Green, #82A Very Pale Blue.

1.25" Advanced Set of 4 Filters #5570
Includes #8 Light Yellow, #23A Light Red, #38A Deep Blue, #56 Light Green.

$39.95 set (2.98)

More Color Eyepiece Filters

Deluxe Set of 8 Filters for 1.25" Includes all the filters in our basic and expansion filter sets.
#5517 **$74.95** (3.45)

Full Set of 12 Filters for 1.25" Includes Basic Set, Expansion Set, Advanced Set.
#5575 **$109** (3.67)

Individual 1.25" Filters- #80A Blue (#11040), #58 Green (#5540), #25 Red (#5536), #15 Yellow (#5532), #21 Orange (#5534), #47 Violet (#5538), #11 Light Yellow-Green (#5530), #82A Very Pale Blue (#5544), #8 Yellow (#5571), #23A Light Red (#5272), #38A Deep Blue (#5273), #56 Light Green (#5274)
$11.95 ea. (2.43)

Moon Filters

Cuts 87% of the light from the Moon. Reduces glare by uniformly reducing light transmitted over the entire spectrum.

.965" #5664 **$13.50** (2.43)
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SkyGlow™ Light Pollution Filters

Enhance your viewing of faint deep sky objects with the best broadband light pollution filter you can buy. Our SkyGlow absorbs frequencies emitted by city lights, allowing transmission of the rest of the visible spectrum, yielding dramatic results.

SkyGlow Broadband Filters—Photographic and Visual
For use in slight to moderately light polluted areas.

1.25" Broadband Filter–fits 1.25" eyepieces.
#5660 **$59.95** (3.45)

Schmidt-Cassegrain Broadband Filter–fits rear cell of Meade & Celestron SC scopes.
#5658 **$79.95** (3.45)

52mm Broadband Filter–For 52mm camera lenses, adapter rings available for other diameters.
#5668 **$79.95** (3.45)

SkyGlow UltraBlock Filters–Visual Only
For severely light polluted areas and faint nebulae.

1.25" UltraBlock Filter–fits 1.25" eyepieces.
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Schmidt-Cassegrain UltraBlock Filter–fits rear cell of Meade & Celestron SC scopes.
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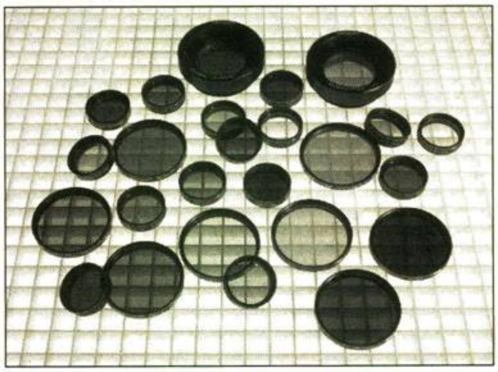

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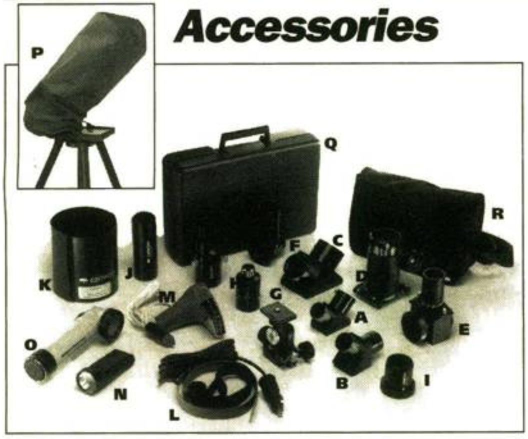

A Star Diagonal Prisms

1.25" Star Diagonal Multi-Coated.
#8763 **$39.95** (2.98)

.965" Star Diagonal Coated optics.
#8761 **$24.95** (2.98)

B 45° Erect Image Diagonals

.965 Diagonal #8759 **$69.95** (3.45)
1-1/4" Diagonal #8753 **$69.95** (3.45)
Size-Adapting Hybrid Diagonal #8755 **$69.95** (3.45)

C 2" Mirror Star Diagonal

Get the widest possible field of view from your Schmidt-Cassegrain Telescope. This star diagonal features a special aluminized and overcoated precision first-surface flat mirror.
#8767 **$89.95** (3.45)

D Rack & Pinion Focusers

These top quality focusers are designed for Newtonian reflectors. Fit any size tubes.

1.25" Focuser #13017 **$42.95** (2.98)
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Advanced features at a low price. Use with Meade or Celestron SC. Easily adjustable prism. Ultra-precise helical focus of your eyepiece, adjustable camera focal plane position. #5139 **$129** (4.19)

F Orion® Premium Off-Axis Guider

High performance, Multi-Coated, precision anodized. Low Orion price! #5144 **$49.95** (3.45)

G Basic Camera Adapters

Combination Eyepiece Projection Tube and Prime Focus Adapter for refractors and reflectors with 1.25" eyepiece holders. Use with T-Ring (sold separately).

.965" #5268 **$24.95** (2.98)
1.25" #5264 **$29.95** (2.98)

H Vari-Power Camera Adapter

Unique sliding barrel design allows variable projection distances during eyepiece projection photography, eliminating the need to change eyepieces when magnification changes. #5262 **$39.95** (2.98)

I Orion® T-Adapter for SC

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K FlexiShield™ Dew Caps

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DC Model #3503
AC Model #3504 **$44.95** (2.98)

10" Dew Zappers—fit all Meade 10" Schmidt-Cassegrains
DC Model #3506
AC Model #3508 **$49.95** (2.98)

M Dew Remover Gun

Moisture that interferes with viewing dissipates quickly with this 12V DC, 156 watt warm air gun. Has 4-1/2' cord. #5601 **$17.95** (2.78)

N Starlite Red LED Flashlight

The Starlite is the only adjustable-brightness night-vision red flashlight. Lifetime solid-state LED can't burn out. Extra efficient electronic circuit for long battery life. Uses one 9-volt battery (not included).
#5714 **$24.95** (2.43)

O Astronomer's Flashlight

Indispensable and indestructible. Has special night-vision red filter and a diffusion lens for even illumination. Requires 2 D batteries (not included).
#5701 **$9.95** (1.79)

P Scope Saver Telescope Covers

Keep your Schmidt-Cassegrain covered and keep the dust and dew away! Fits the telescope either on the tripod or in the case. Blue waterproof nylon fabric. Drawstring closure with cord lock.

8" Model #15130 **$33.95** (2.43)
10"-11" Model Fits Meade 10" and Celestron 11"
#15131 **$39.95** (2.43)

Ask about other sizes.

Q Deluxe Eyepiece Case

This durable case with double hinges holds up to 10 eyepieces plus barlow. Die cut foam insert for snug fit. O.D. 8-1/2"x12-1/2"x3-1/8".
#5913 **$17.95** (2.78)

Field Tripod Tote Bag

With padded insert to separate wedge from field tripod during transportation. For wedge combinations of Schmidt-Cassegrains up to 10" aperture. Allows storage without changing polar alignment. Tear and mildew resistant blue Cordura nylon.
#15096 **$79.95** (5.19)

Observer's Chairs

Make observing more comfortable and enjoyable with one of these great chairs.

Standard Model—Has adjustable height center column and padded vinyl seat. Folds for easy storage. #5935 **$39.95** (4.70)

Deluxe Model—Is much heavier-duty, built for professional musicians. Extra thick padding, wide footprint. Adjustable and disassembles for storage.
#5934 **$89.95** (8.02)

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Ideal for operating your telescope plus higher power-consuming accessories such as an Orion Dew Zapper. Battery is encased in high impact polystyrene. Carrying case of Cordura nylon with shoulder strap and handle. Wt. 10 lbs.
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Moreover it has encouraged me to look back into my own time, helping me rediscover a simple pleasure, a lost love. My midlife attempt to do astronomy modeled, in a totally unexpected way, how I got to be so uncomfortable with my midlife. My solution to the astronomy puzzle turned out to be a piece missing from the puzzle of my life.

There are moments now, on the high desert, under dark skies, when I can feel that excitement and energy of youth again — when all things seem possible. It's at those moments that I feel incredibly hopeful, incredibly young.

"May I help you?"

I looked up from my magazine and eyed the middle-aged customer standing in front of the curmudgeon, nervously pawing the ground with his toe. I leaned over and whispered, "Say 'yes.' He can help you."

ROCKY MOUNTAIN SKY

by Eric L. Muller

The Rocky Mountains are a place of discovery for all sorts of vacationers. Some are skiers, wearied by cold, scraping runs down New England ice floes, who fly west to find vast fields of virgin powder. Some are refugees from asphalt and aluminum siding who find peace in a wooden cabin tucked away in the quiet of a spruce forest. Still others are do-it-yourself gourmets who discover that hooking a trout dinner from a nearby stream is as easy as defrosting a box of Mrs. Paul's.

I recently flew to the Rockies and discovered the horizon. Now most people think of the horizon as a place on Earth, something they can find from just about anywhere. But I am an amateur astronomer, and for me the horizon is the place in the night sky where darkness meets earth.

In suburban New Jersey, where I live, the night sky never meets earth. It reaches down to an altitude of about 20°, where it succumbs to the glare of the New York metropolitan area. The New Jersey horizon is really nothing but an opaque, washed-out haze. It is a second Milky Way, a manmade one, with none of the delicate beauty of its natural counterpart.

The Rocky Mountain spot where I found the horizon was Frisco, a tiny town nestled in a small valley some 9,000 feet up in Colorado's Ten Mile Range. Minutes from four top ski resorts, Frisco was my destination for a late-winter skiing vacation. However, shortly after making my travel plans, I learned that the Moon would be New on the third night of the trip. New Moon, high elevation, and a dark mountain sky — what started as a skiing trip instantly became a stargazing opportunity I couldn't miss.

The first three evenings in Frisco were overcast, and I began to despair that I had lugged my Astroscan telescope to Colorado in vain. But the fourth night proved to be magnificent: It was crystal clear, with calm winds and tolerable temperatures in the 30s. I drove to a clearing in the woods about a mile from town, ignoring the mental images of an attack by hungry coyotes or shotgun-toting backwoodsmen, and stepped out of the car.

I found myself under a dizzying dome of stars, a spectacular array that left me mumbling to myself. The night was so clear that the vacuum of space seemed to tug me gently skyward. I quickly set up my telescope and began searching for the many wonders of Orion and his neighbors.

After getting my fill of these familiar objects, I let my gaze drop lower, past blazing Sirius and toward the treetops. I could not believe what I saw. There, glowing through a gap in the mountains, was a wide, sparkling field of stars. I had stumbled upon the lower reaches of the Milky Way — the real one, that is — in a part of the sky where I was accustomed to seeing only its hideous manmade cousin. High in the Rockies, I had found the horizon, and it was more beautiful than I had imagined.

My eyes did not leave this shining gap in the Ten Mile Range for the rest of the evening. For me it was a new and uncharted piece of the sky — I let my gaze roam over this stunning region that the Rocky Mountain night revealed to me.

Late winter weather changes quickly in the Colorado mountains, and that glorious night turned out to be my last glimpse of the heavens during my trip. I contented myself through the remaining days with carving turns on the slopes and hiking across snow-covered mountainsides cloaked in spruce and aspen. Each of these was a wonderful experience, well worth the trip west. But of the new things the Rockies showed me, the most spectacular was a sparkling, deeply jeweled piece of the night sky called the horizon. ☐

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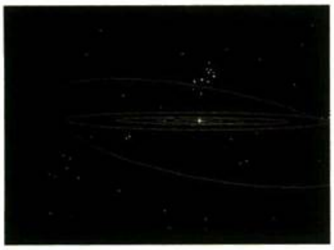

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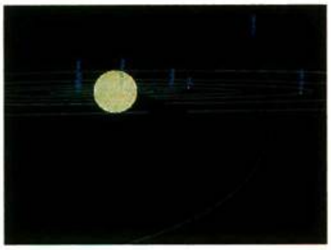
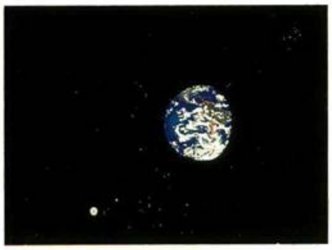
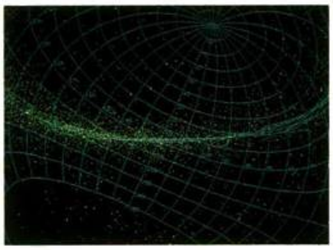


Jupiter expelling comet Lexell from solar system in 1779.

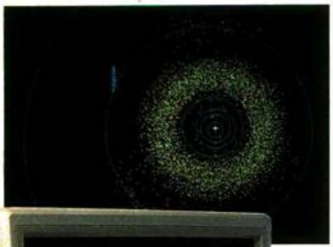


Earth and Moon in Taurus, 16 Oct 2000.

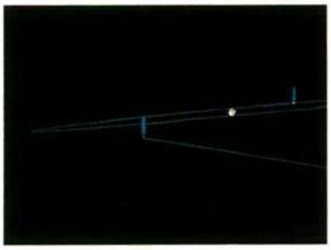


Celestial Skymap with asteroids along the ecliptic.

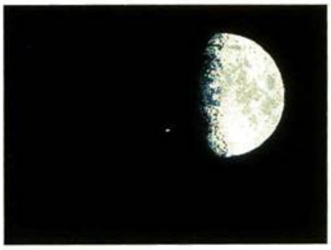
Polar view of asteroid belt – Jupiter and the Trojan asteroids.



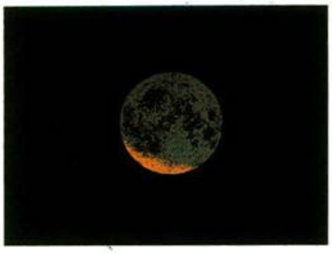
Asteroid 1991BA passing close to Earth. 18 Jan., 17.5h, 1991.



Saturn slipping behind the moon. From Osaka Japan, 8 Oct. 1962.



Lunar eclipse of 9 Feb. 1990, near maximum.



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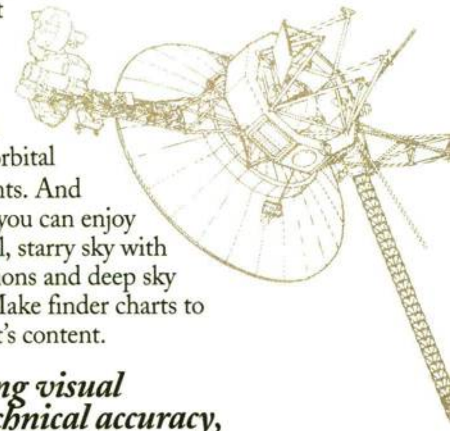

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BLACK HOLE FOUND IN THE WHIRLPOOL

X marks the spot in a remarkable new image from the Hubble Space Telescope. The spot in question is the location of a black hole with a mass of two million suns lurking at the center of the Whirlpool Galaxy, a radio galaxy in Canes Venatici. The galaxy, known as M51, is a favorite target of backyard astronomers since it appears face-on in the sky, providing an unobstructed view of its spiral arms and bright nucleus.

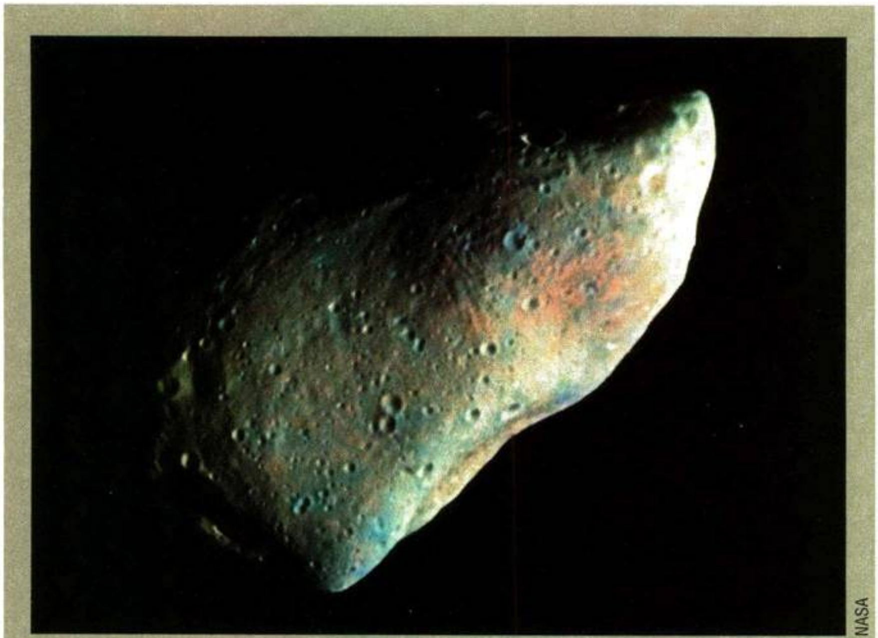
Hubble's new image of M51 shows just the tiny core of the galaxy, a bright region crossed by two dark lanes. The observations were made by Holland Ford (The Johns Hopkins University and Space Telescope Science Institute) and his Faint Object Spectrograph Team co-investigators.

"The pictures taken with the Planetary Camera show a striking, dark X silhouetted across the nucleus. The X is due to absorption by dust and marks the exact position of the nuclear black hole," says Ford. "If these ideas are correct, M51 provides the first direct view of a large ring, or torus, that both fuels a massive black hole and hides the hole from direct view."

The dark rings of dust orbiting the black hole lie almost perpendicular to the plane of the spiral galaxy's disk. As material swirls around the black hole, some is funneled into high-speed jets streaming away from the hole's polar regions. But unlike jets seen in other radio galaxies, the Whirlpool's jets are not pointed out of the plane of the galaxy. They instead shoot head-on into the disk of the galaxy. As a result, the fast-moving material plows into the dust and gas of the galaxy's disk like two blowtorches, creating hot bubbles of gas on either side of the black hole. Researchers see the emission from these jets in the Hubble image as two bright spots, one above and one below the X.

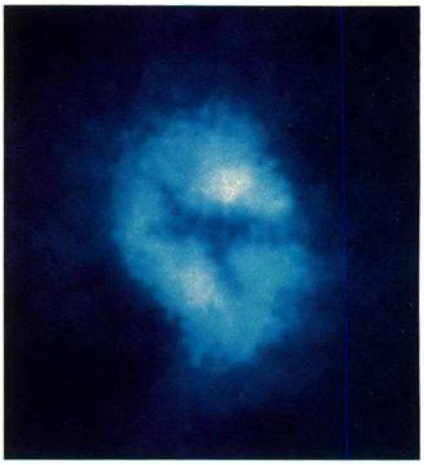
Surrounding the black hole's equator is at least one torus of cold gas and dust. We see it edge-on as the widest dark band running horizontally through the image. Its diameter is estimated to be 100 light-years across. The dark ring hides the black hole itself and its adjacent disk of infalling hot gas. The dusty ring confines the radiation from the hot gas so that it can escape only through the "doughnut hole" via the conelike jets above the hole's polar regions.

The second bar running diagonally across the nucleus is a puzzle. It may be a second dust ring orbiting the black hole. Or it could be rotating gas and dust from the disk of the galaxy interacting with the high-speed jets. "The safest interpretation," warns Ford, "is that the slash is a caution sign, showing that we do not yet fully understand what is happening in the center of M51."



NASA

ASTEROID 951 GASPRA shows numerous craters in this image made by the Galileo spacecraft in October 1991. The subtle color variations on the asteroid's surface are superimposed on an image that depicts the asteroid with a resolution of 150 feet. Bluish areas represent high reflectivity, probably due to recently exposed olivine. Reddish areas represent lower reflectivity. The asteroid's dimensions are 12 by 7.5 by 7 miles. Having imaged Gaspra, the Galileo spacecraft will pass close to Earth next December, and a month later engineers will attempt to shake loose the spacecraft's jammed high-gain antenna. Should the attempt fail, the mission to Jupiter (arrival: December 1995) will proceed using the craft's low-gain antenna.

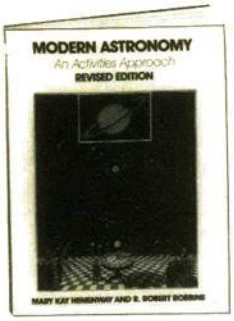


H. Ford (JHU/STScI), the Faint Object Spectrograph IDT, and NASA

A BLACK HOLE HIDES behind the two dark lanes of dust revealed in Hubble's high-resolution image of the Whirlpool Galaxy.

COLLISION SPARKS STARBURST GALAXY

The peculiar galaxy designated Arp 220 is experiencing an extraordinary burst of star formation as the result of a collision between two massive spiral galaxies. The collision is also producing star clusters far larger than any seen previously in the universe. These conclusions stem from new photographs of the galaxy taken by the Hubble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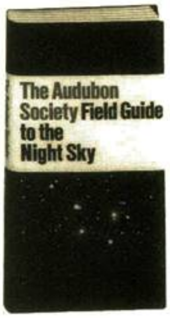
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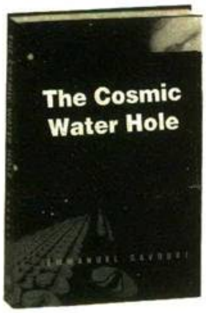
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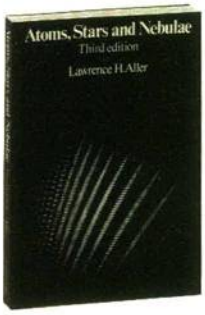
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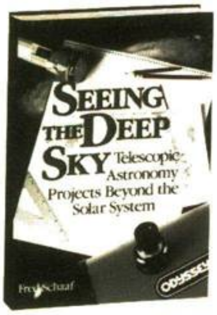
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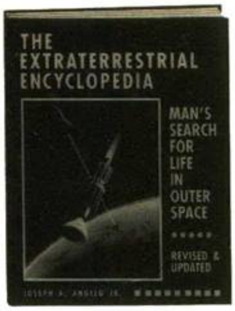
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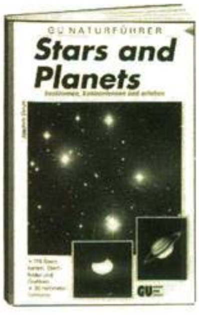
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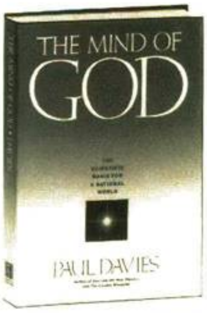
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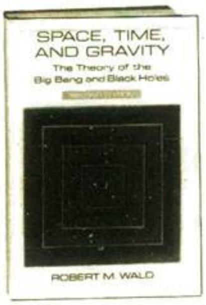
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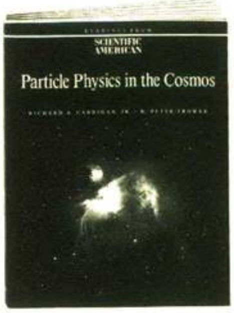
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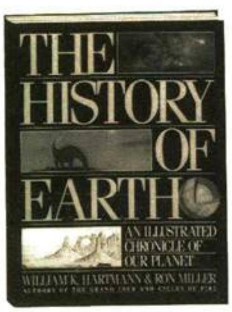
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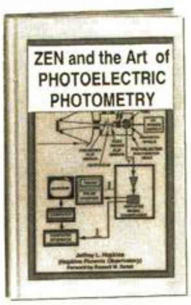
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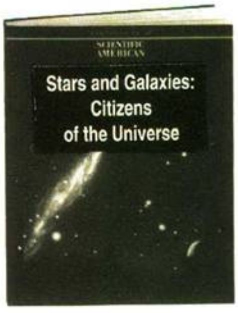
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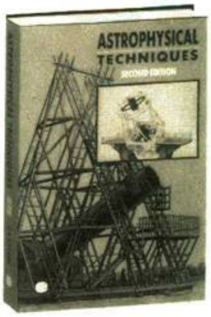
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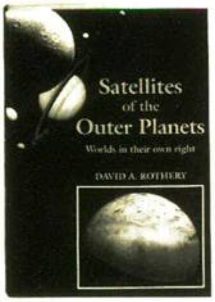
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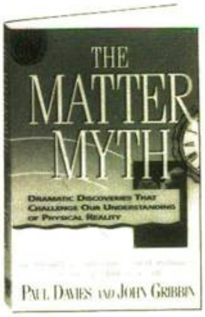
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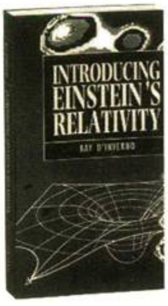
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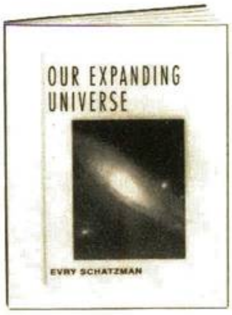
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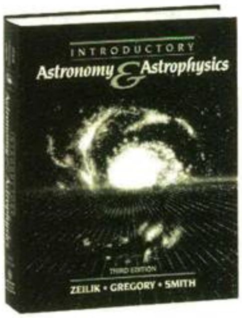
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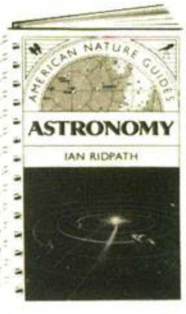
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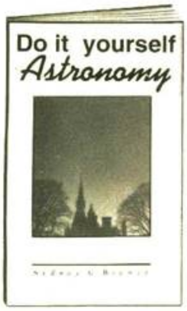
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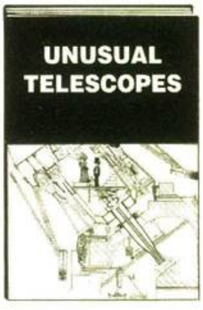
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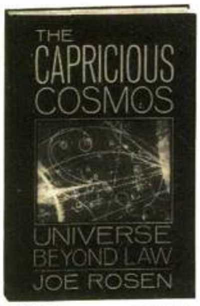
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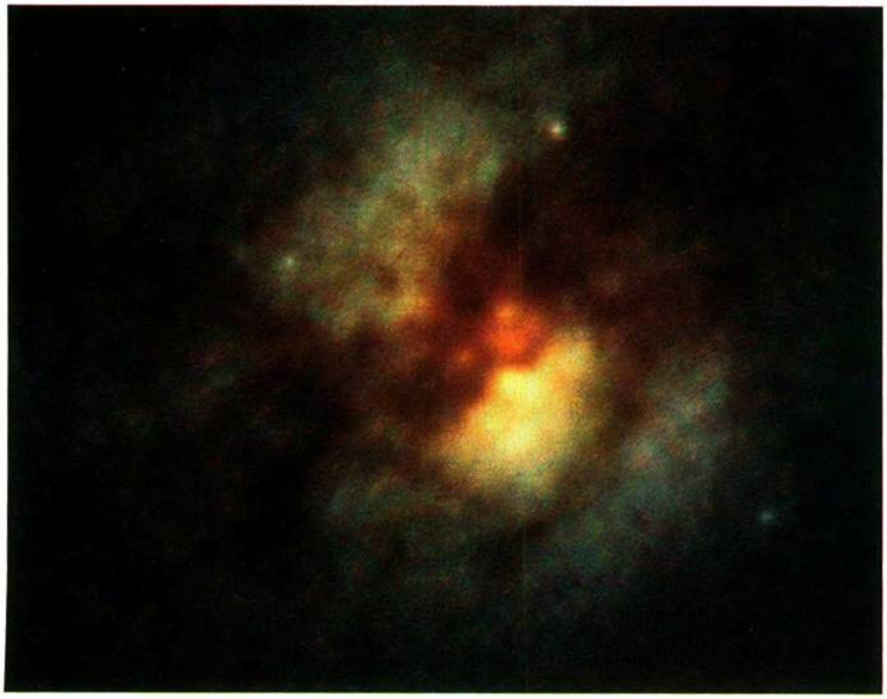
Space Telescope's Wide Field/Planetary Camera.

Arp 220 first gained notice in the 1980s, when the Infrared Astronomical Satellite showed it to be the brightest member of the class of ultraluminous infrared galaxies, galaxies that release 95 percent of their energy in the infrared part of the spectrum. In 1988, astronomer David Sanders of the University of Hawaii proposed that the merger of two large spiral galaxies triggered the starburst activity observed in these galaxies. The collision caused much of the gas and dust to fall toward the center, where its high density sparked a high rate of star formation.

Now Edward Shaya and Dan Dowling of the University of Maryland and the Wide Field/Planetary Camera team have taken the sharpest images yet of a starburst galaxy, and these seem to support Sanders' model. The team discovered six luminous knots in Arp 220's central 2,000 light-years that turn out to be young, super-bright star clusters ten times the size of any known cluster. (Others may lie hidden deep in the galaxy's prominent dust lane.) The two brightest clusters appear to be the nuclei of the now-merged galaxies.

The core of Arp 220 promises to be a unique laboratory for studying supernovae and the evolution of massive stars. Supernovae are the explosions of large stars — the type common in bright young clusters in star-forming regions. Over time, the core of Arp 220 may resemble a string of firecrackers going off. Shaya estimates that the massive clusters should produce several supernovae per year.



E. Shaya, D. Dowling, and NASA

HUGE STAR CLUSTERS larger than any seen before dominate the light from the starburst galaxy Arp 220. This HST image shows six of these clusters, which appear as luminous knots in the galaxy's core. More may be hidden by the dark lane of dust cutting through the galaxy's center.

EUVE SUCCESSFULLY LAUNCHED

Very hot objects with temperatures from 100 thousand to 2 million kelvins radiate strongly in the extreme ultraviolet part of the spectrum, which is blocked by the ozone layer before it can reach astronomers on the ground. On June 7, the first space-based observatory designed to study this energetic radiation, NASA's Extreme Ultraviolet Explorer (EUVE), was launched into orbit from Cape Canaveral on an unmanned Delta-II rocket.

The first countdown on June 6 was scrubbed at T–4 minutes because of minor technical problems at support sites in Maryland and Antigua. The next day the count was held for 16 minutes while the Mir space station and an airplane cleared the Delta's launch trajectory. Liftoff from launch pad 17-A came at 12:40 p.m. EDT, and 71 minutes later EUVE was in a 300-mile-high orbit inclined 28 degrees to the equator.

USAF
DELTA
EUVE

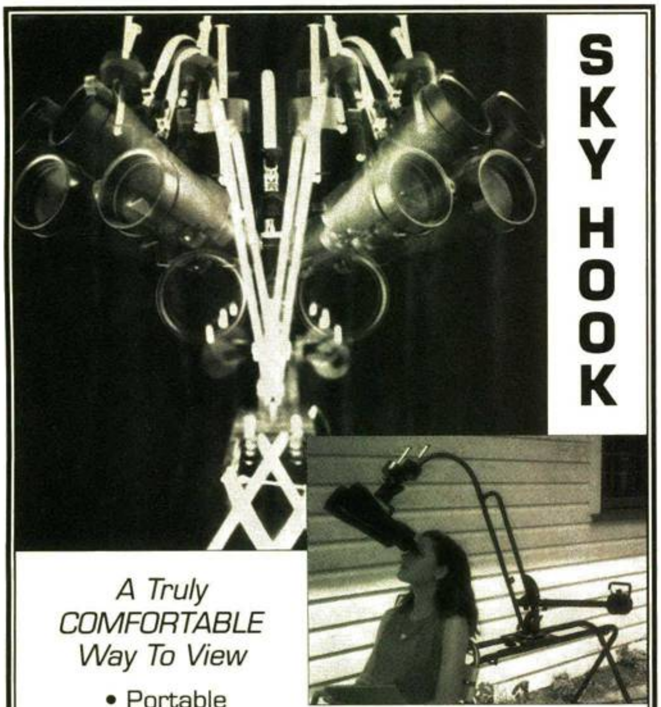
Sean Sullivan

THE EXTREME ULTRAVIOLET EXPLORER was launched on June 7, 1992, from Cape Canaveral, Florida.

EUVE will spend six months conducting an all-sky survey with a resolution of 6' in the wavelength range of 70 to 760 angstroms, followed by several years of detailed study with its battery of four 16-inch telescopes. The extreme ultraviolet is the last unexplored region of the electromagnetic spectrum, and no one knows what EUVE will see. — *Sean Sullivan.*

DEEP-SPACE PROBE SET TO BEGIN

Astronomers at the University of Southern California at Santa Cruz plan to use the world's largest optical telescope, housed in the W.M. Keck Observatory in Hawaii, to examine 15,000 galaxies in the most ambitious deep space survey yet. The project, called DEEP for Deep Extragalactic Evolutionary Probe, will map the positions and velocities of galaxies in several small patches of sky. The survey technique will produce views of the universe along several narrow pencil beams and should reveal structures such as walls of galaxies and the voids between them.



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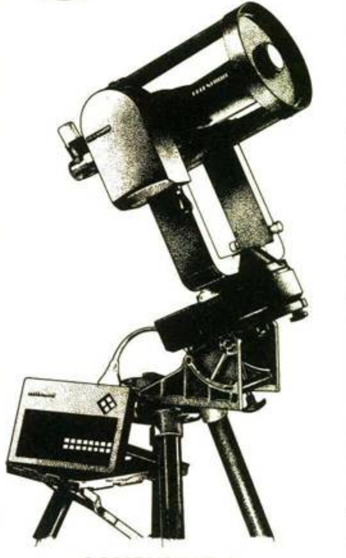

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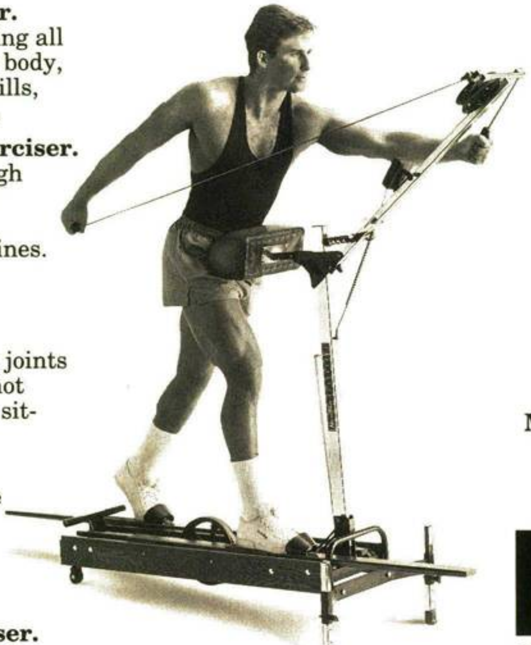

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Each survey field will be only a few arcminutes wide but will probe outward several billion light-years, revealing the nature of galaxies when the universe was half its present age. Said David Koo, one of the the project's coordinators, "We may even find the Holy Grail of astronomy — determining the curvature of the universe itself."

The National Science Foundation awarded preliminary funding of $150 thousand for DEEP late in 1991. The survey will begin later this year as one of the first projects for the new Keck telescope. The entire survey is expected to cost $4 million and will take the rest of the decade to complete.

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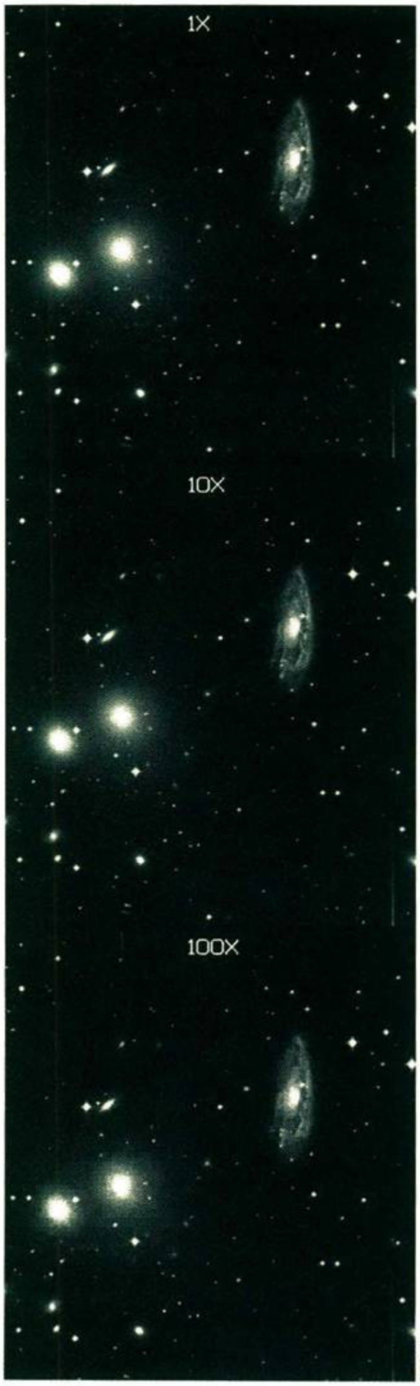
Imagine turning your home computer into a professional telescope capable of displaying millions of stars and galaxies located anywhere in the sky. In just two years, that dream will become reality.

Astronomers at the Space Telescope Science Institute (STScI) are busy converting a vast sky survey into a digital format that can be stored on CD-ROMs. The effort grew out of STScI's preparation of the Guide Star Catalog, which provides the coordinates of stars used by Hubble for acquiring and locking onto celestial targets. The basis for this catalog is photographic sky survey plates taken with the 48-inch Schmidt telescope at Palomar Observatory and the United Kingdom Schmidt telescope at Siding Spring in Australia. Each of those plates covers an area about the size of the bowl of the Big Dipper and reveals objects down to 21st magnitude.

To create the desktop universe, the astronomers will turn to an algorithm that compresses the data by a factor of 10. That will squeeze the data enough to fit it on 100 CD-ROMs. However, at an estimated cost of nearly $2,000, the set is geared primarily to libraries and university astronomy departments.

STScI, however, also plans to compress the plate scans by a factor of 100 within the next two years. This will squeeze the entire survey (to 19th magnitude) onto 10 CD-ROMs. At an estimated cost of around $100, many amateur astronomers and schools could afford this set. Though this super-compressed version won't have the same resolution as the 10-to-1 compression, it will be good enough for preparing simple finder charts and developing classroom exercises.



STScI

THE UNIVERSE ON COMPUTER is only a couple of years away. These three pictures show a section of the digitized sky survey at different compression factors. The sample image is of an 11.3-arcminute-square region of the Hydra galaxy cluster, showing the spiral NGC 3312 and the ellipticals NGC 3311 (right) and NGC 3309 (left). The top image shows the actual digitized scan of the southern sky survey plate, the middle image is compressed by a factor of 10, and the bottom image by a factor of 100.

ASTRONOMY'S 1993 FEDERAL BUDGET

Though President Bush's 1993 budget proposal contains a modest increase for astronomy, this area received the smallest increase within the National Science Foundation's math and physical sciences division. The small increase means that the international Gemini project to build twin 8-meter telescopes — one on Mauna Kea and one in the Southern Hemisphere — will encounter delays.

The National Optical Astronomy Observatories (NOAO) received only a 3.5 percent increase, probably insufficient to offset inflation. U.S. participation in Gemini further reduces the funds available in NOAO to operate Kitt Peak National Observatory, the National Solar Observatory, and the Cerro Tololo Inter-American Observatory (CTIO) in Chile. The increase also provides no allowance for the expected inflation by $400 thousand to $500 thousand in the cost of running CTIO. And to heighten the possible problems, Congress usually passes a budget that contains less money for NOAO than the president's budget does.

Plusses in the budget include funds for the Laser Interferometric Gravitational Wave Observatory, more commonly known as LIGO. The National Radio Astronomy Observatory will finish construction of the Very Long Baseline Array and will receive funds to repair equipment used for an interferometer. Arecibo Observatory will receive a new high-efficiency secondary mirror and equipment to reduce radio interference. The improvements should increase the performance of the radio telescope by a factor of 3 to 10.

STAR CAPTURED BY BLACK HOLE?

X rays emitted by the Seyfert galaxy NGC 6814 change intensity regularly with a period of 12.130 seconds. The variability could well be the signature of a star captured into orbit around a supermassive black hole at the galaxy's center. Astronomer Chris Done of Leicester University in England announced the results at the April meeting of the Royal Astronomical Society in Durham.

Astronomers think the 12.130-second period may be the orbital period of a star captured by the black hole that lies at the galaxy's center. The periodic X-ray emission would then be caused by the interaction of this star with the stream of gas feeding the black hole. Astronomers will conduct follow-up studies this winter.

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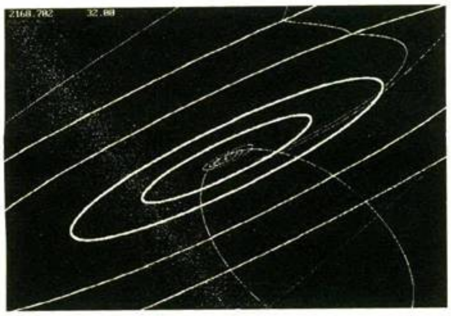

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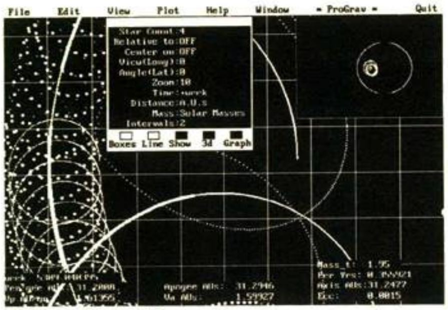

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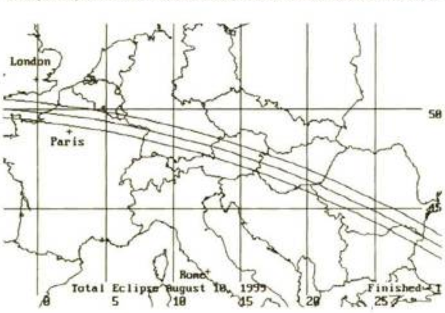

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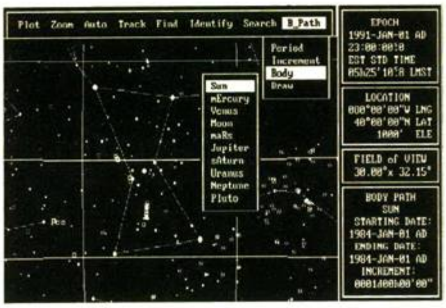

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TEXAS TALES AND RIVERSIDE REPORT

A record 800 people attended the 1992 Texas Star Party in Fort Davis, Texas, between April 26 and May 3. As it has for the past 10 years, the Prude Ranch played host to all-night observing, astrophotography, daytime talks, telescope judging, and good old-fashioned socializing with fellow amateur astronomers. The event, one of the "big three" star parties (along with Stellafane in Vermont and Riverside in California), has grown to the point that the organizers, this year the Oklahoma City Astronomy Club, are concerned that the ranch will not easily handle future growth.

The most renowned feature of the Texas Star Party — the inky black skies of west Texas — cooperated nicely throughout much of the event this year. By midweek the throngs of observers were exhausted from staying up all night and hardly minded that three nights at the week's end were substantially cloudy.

This year's TSP talks included an exposition by Eugene Shoemaker of the U.S. Geological Survey of the danger posed by comets and asteroids that may impact Earth. Harold Corwin, from Caltech's image-processing lab, described the history of the discovery of the galaxies and how they were slowly catalogued. Author Richard Berry described the "coming golden age of amateur astronomy," citing why amateur astronomers are entering a very exciting and challenging period in the years ahead. Amateur telescope maker Peter Ceravolo of Gloucester, Ontario, analyzed the quality of telescope optics and sized-up currently available models. David Anderson of Southern Methodist University wowed the audience with three-dimensional computer-enhanced images of the surface of Venus.

The 1992 star party filled the minds of those who attended it with excitement and future challenges. Yet a feeling of sadness hung over the event with the tragic loss of one of the star party's most ardent supporters. Earlier in the week Al Bowen of Dallas suffered a fatal heart attack, and the loss overwhelmed many of his friends in attendance at TSP. Organizers created an endowment fund in Bowen's name to be used for combating light pollution.

Amateurs at the TSP honored two of their own this year. Richard Berry won the Omega Centauri award for his outstanding contributions to the field of astronomy as an author and editor. Writer and observer David Higgins won the Lone Stargazer award for his exceptional abilities in observing the sky and sharing it with others.

The experience of seeing the Milky Way arch overhead was a grand one for this year's TSP attendees. They could only wish to see the winter sky from such a dark site. This year they can get their wish, as the Okie-Tex Star Party will be held at the Prude Ranch from October 19-24, 1992. Evening speakers will include Frank Bash, director of McDonald Observatory, Jim Secosky, one of the amateur astronomers who used the Hubble Space Telescope, and Dave Eicher of ASTRONOMY magazine. For more information, write Beryl Cadle, Okie-Tex Registrar, P.O. Box 21221, Oklahoma City, OK 73156.

The other major western star party, also held in the spring, is the Riverside Telescope Makers' Conference. Each year, approximately 2,000 people converge on the site near Big Bear Lake, California, for what has become the hobby's biggest swap meet, product fair, and exhibit of amateur telescope-making craftsmanship. The innovative telescope designs from amateurs provide a hint of what commercial products we may see in the future.

This year, some of the most wonderful views were through homemade binocular telescopes. Jim Carlisle from San Luis Obispo, California, wowed the crowd with views through his twin 10-inch Newtonians. The two optical assemblies were stacked vertically in a design first developed by William Herschel in the 1700s. An ingenious sliding tube allowed each person stepping up to the scope to easily merge the two images into almost three-dimensional views of deep-sky objects. Across the field, Jim Stevens of Phoenix, Arizona, showed off a single-mirror 17.5-inch Newtonian built to accommodate a binocular viewer at the scope's prime focus. Although this arrangement took an image from a single optical train and split it into two, the resulting view was impressive, so much so that it was easy to believe that seeing the universe with both eyes open might be "The Next Big Thing" in amateur astronomy.

Inside the meeting hall, the discussion got lively during a seminar on optical quality. Kevin Medlock of Epoch Instruments, Paul Jones of Star Instruments, author Terence Dickinson, and telescope maker Peter Ceravolo spoke about ways to produce the most perfect image possible from any telescope, indeed for producing the most perfect telescope, period. It was clear that this telescope was a mythical beast — as one audience member quipped, "I want a 17-inch telescope that is 3 inches in diameter!" The audience broke into applause at Jeff Shroeder's statement, "A portable telescope being used is better than a perfect telescope in the closet."

This was a year of change for Riverside. For the past two decades, the conference has been organized by a dedicated group with Cliff Holmes, conference founder, at the helm. Earlier this year, Cliff and several colleagues handed over their conference duties to Steve Edberg and a new generation of amateurs. The hundreds of people present at the Saturday night presentation ceremony gave Cliff Holmes, Ashley McDermott, and their fellow committee members a standing ovation for their years of tireless work staging the Riverside meeting. If the success of this year's Riverside is any indication, fans of this annual mecca for amateur astronomers can look forward to many more years of great meetings and good times. — *Alan Dyer and Dave Eicher*

LEAGUE ANNOUNCES YOUTH AWARD

To encourage more student involvement in amateur astronomy, the Astronomical League has created an award to recognize the outstanding high school-aged astronomer in the United States. The award will be presented annually to the young astronomer demonstrating national achievement in one or more of the following areas: research, scholarship, observing, local club activities, regional and national organization activities, writing or publishing, public education, astrophotography/CCD imaging, and telescope and equipment design or construction.

The Astronomical League will announce the first National Outstanding Young Astronomer Award on January 15, 1993. Deadline for applications or nominations is September 30, 1992. To obtain instructions, write to Charles E. Allen III, Award Coordinator, 1007 Rollingwood Lane, Goshen, KY 40026.

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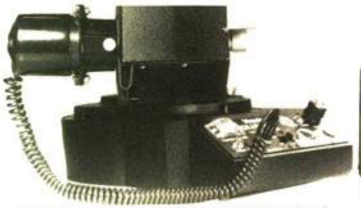

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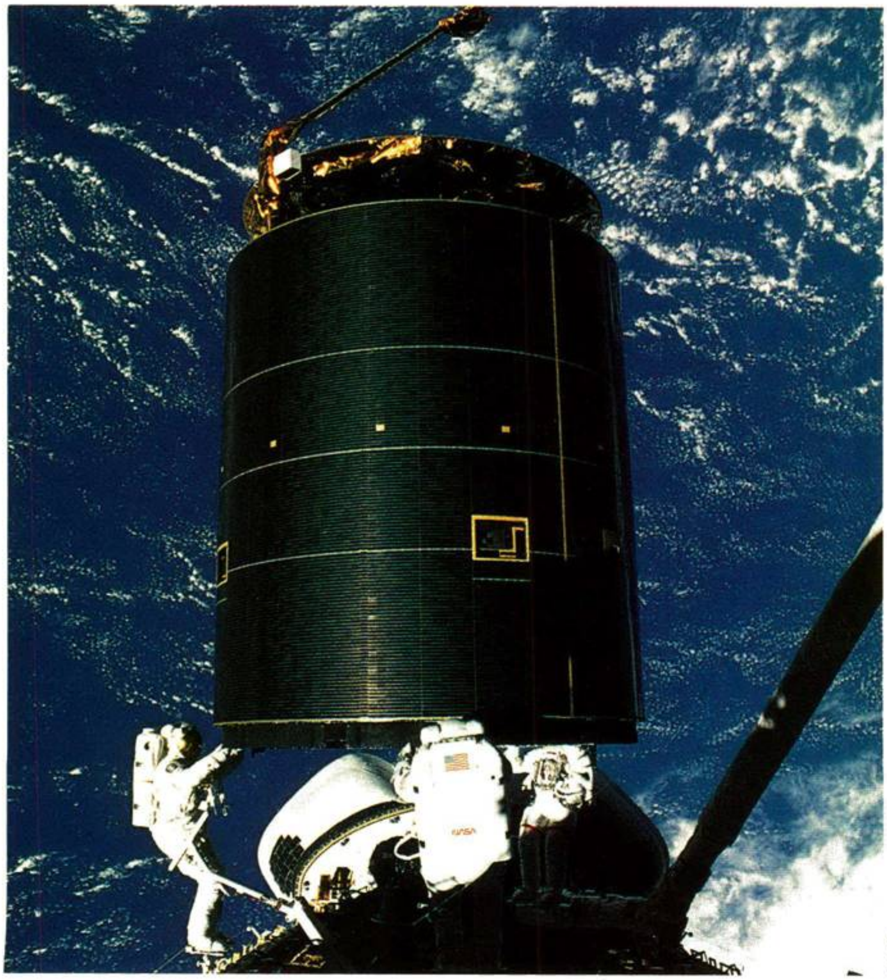
Color Filter Wheel assembly shown attached to Model ST-6 CCD Imaging Camera. Filter Wheel has four filter positions and a star diagonal position allowing an eyepiece to be positioned at a focus which is parfocal with the Model ST-6.

NEW SHUTTLE RESCUES SATELLITE

The first mission of the new shuttle Endeavour proved far more challenging than anyone had expected. What was envisioned as a "simple" rescue of a wayward communications satellite turned into a grueling mission that required three rendezvous and set several records for space walking. Still, Endeavour's inaugural flight was an unqualified success — not only did the rescue come off, but the shuttle performed nearly flawlessly and NASA gained valuable experience for the 1993 mission to fix the Hubble Space Telescope.

The Intelsat VI satellite had been stuck in a useless orbit since shortly after its launch in March 1990, when explosive bolts designed to separate the satellite and its kick motor from the Titan 3 launch rocket failed to fire. Instead of reaching geosynchronous orbit 22,300 miles above Earth, Intelsat VI limped along some 22,000 miles lower. Endeavour's mission: grab the satellite, attach a new kick motor, and release the combination so Intelsat VI could be boosted to the right orbit.

The first rendezvous between Endeavour and Intelsat VI came three days after Endeavour's May 7 launch. The plan called for space-walking astronauts Pierre Thuot and Richard Hieb to place a "capture bar" on the back of the satellite. (The capture bar gives the shuttle's remote manipulator arm something to grab onto.) Unfortunately, as soon as Thuot touched the satellite with the capture bar, the satellite became unstable. Three more failed attempts later, the astronauts called it a day.


NASA

SUCCESS AT LAST! Astronauts Richard Hieb, Thomas Akers, and Pierre Thuot (left to right) finally grab hold of the massive Intelsat VI satellite.

Within two hours after the shuttle departed, controllers for Intelsat/Hughes regained control of the satellite. Meanwhile, the astronauts and ground support worked out a revised plan for the next day. But the second rendezvous proved no more successful than the first, and five more attempts to attach the capture bar failed.

Fortunately, mission commander Daniel Brandenstein and mission pilot Kevin Chilton had flown Endeavour so precisely during the first two rendezvous that they had enough propellant left to allow a third and ultimately successful rendezvous. Intelsat/Hughes again regained control of Intelsat VI, and on May 13, Endeavour approached the satellite once more. This time Thomas Akers joined Thuot and Hieb in the shuttle's cargo bay, making this the first three-person extravehicular activity (EVA) in history.

The three astronauts spent 8 hours and 29 minutes outside the shuttle, another EVA record (the previous record was set on the Moon by Apollo 17 astronauts Eugene Cernan and Harrison Schmitt). As Brandenstein piloted Endeavour to within 8 feet of Intelsat VI (both were traveling at 17,500 miles per hour), the three space-walking astronauts each simultaneously grabbed one of the "solar drum positioner" units on the base of the satellite. With the satellite under their control, Hieb managed to attach the capture bar to Intelsat VI.

Then astronaut Bruce Melnick, who was in the orbiter, grabbed the bar with the manipulator arm and placed the satellite on the new motor Endeavour had brought along. The astronauts then deployed the satellite and later fired the motor, sending Intelsat VI on its way to geosynchronous orbit.

Endeavour's flight showed the successes as well as the pitfalls of working in space. The experience can only help NASA as it prepares for the Hubble repair mission, currently scheduled for December 1993. Though the number and complexity of tasks facing the astronauts on that mission are much greater than they were on the Intelsat VI rescue mission, HST was specifically designed for shuttle servicing. If the astronauts on the Hubble mission meet with as much success as Endeavour's crew did, the future of the Space Telescope should be bright indeed. □

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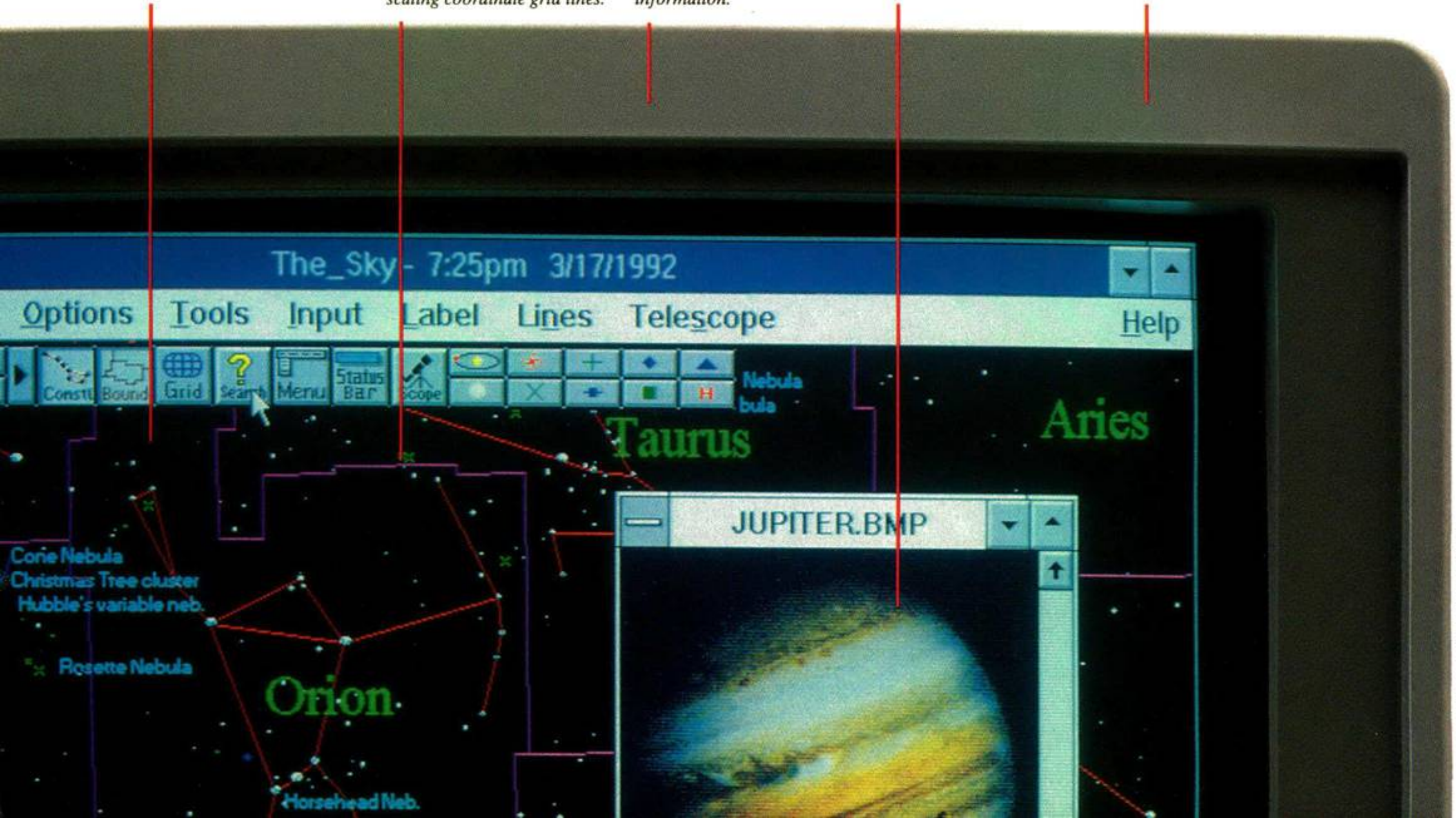
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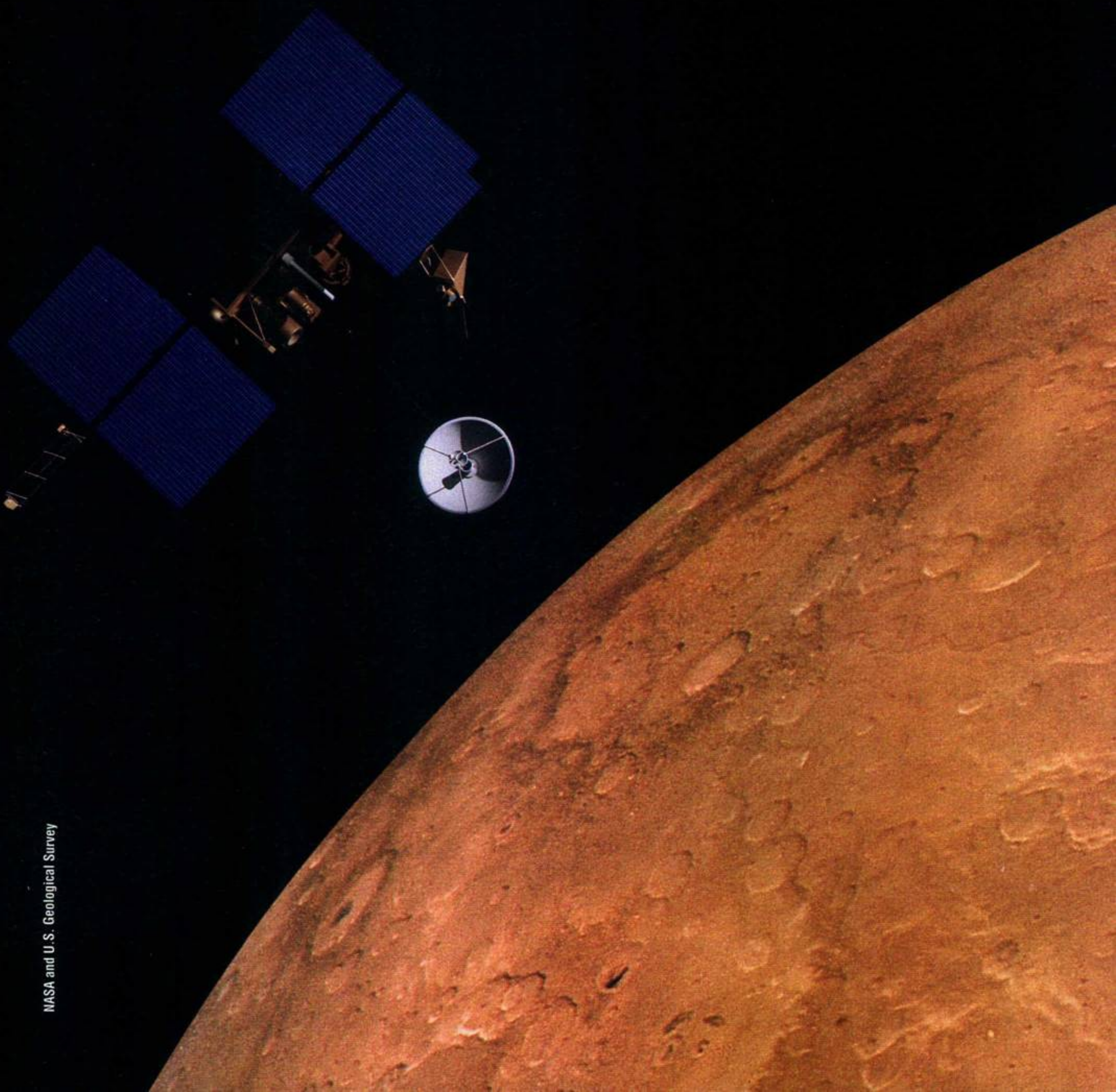
ACTUAL UNRETOUCHED PHOTOGRAPH

MARS OBSERVER:
Return to the Red Planet

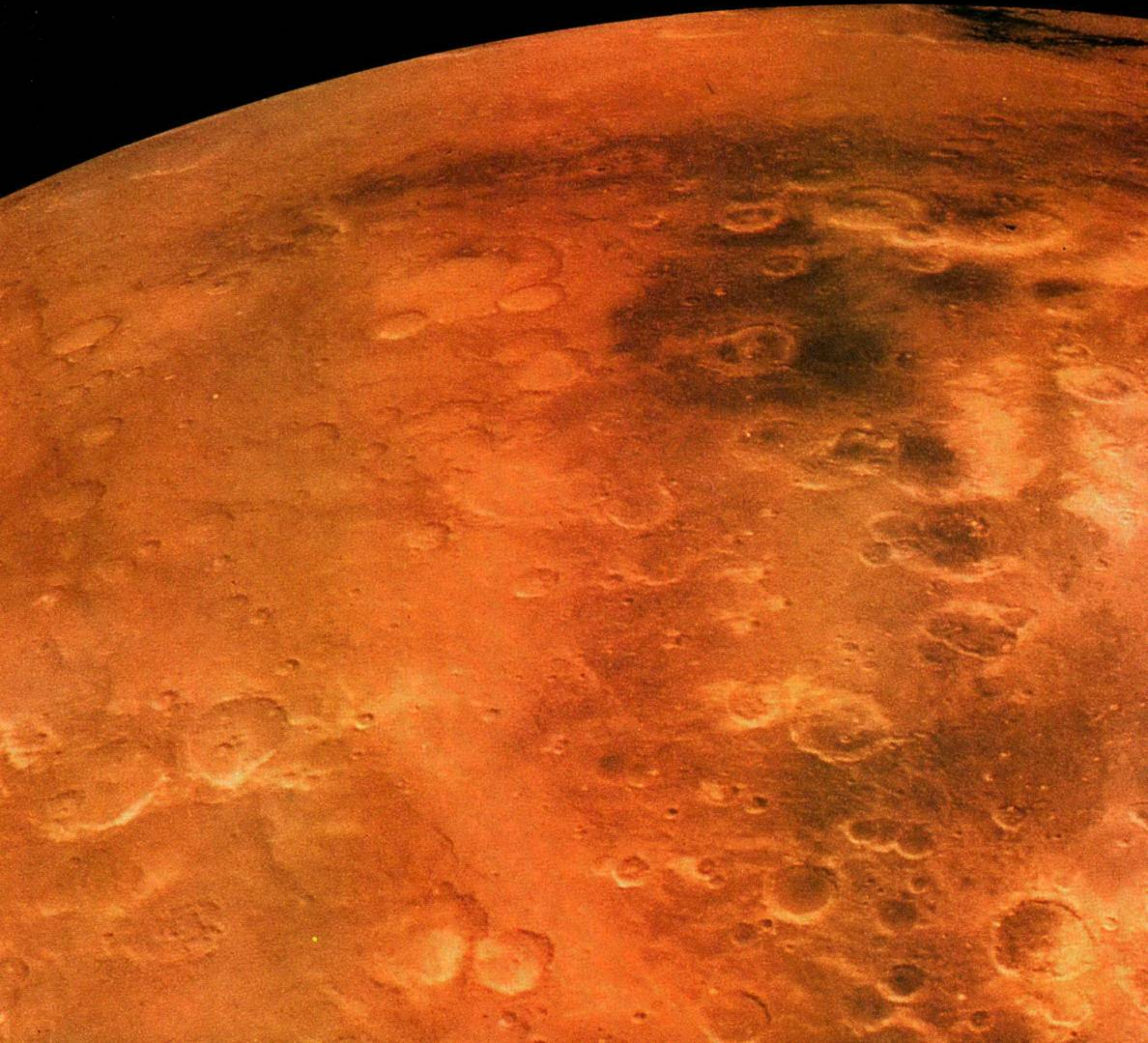
This autumn the United States launches its first mission to Mars since the Viking probes of the mid-1970s.

by Diane Ainsworth



NASA and U.S. Geological Survey

September 16 is a big day for planetary astronomy. If all goes well, a rocket will lift off from Pad 40 at the Kennedy Space Center carrying the United States' first mission to Mars in 17 years. Though the probe has received little fanfare during its development, the new Mars Observer spacecraft promises to rewrite the textbooks.



"We go to Mars this time not to explore, but to observe," says Arden Albee, project scientist for the mission. During Mars Observer's planned two-year stay orbiting the planet, the unmanned craft will thoroughly map the atmosphere and surface of Mars, providing a more complete global picture of Mars than we currently have of Earth.

Explains Albee, "As with the Earth Observing System planned for the late 1990s, Mars Observer will give us a systematic body of data gathered at the same time about a planet. While no single instrument will make an incredible discovery, all the instruments will work together to allow us to test our models of how Mars works."

Mars Observer is an important mission in itself, but it also plays a critical pathfinding role for future Mars exploration. A series of unmanned missions to follow Mars Observer is on the drawing boards. If implemented, these plans will turn into a fleet of spacecraft to Mars over the next decade. All will rely on the detailed maps made by Mars Observer.

The World Next Door

Mars is the planet most like Earth. Home to mythical Martians and fictional civilizations, Mars has inspired generations of writers and visionaries. At the turn of the century, astronomer Percival Lowell captured the public's imagination with assertions that he had seen canals on Mars, certain evidence, he claimed, for a dying race of intelligent creatures.

By the 1950s and early '60s theories of Martian life had become less romantic. The canals had proven to be optical illusions and the ancient Martian civilizations had been relegated to the imaginations of science fiction writers. The most any life seekers could hope for was a vision of primitive plant life clinging to existence on the cold Martian soil. In 1976, two Viking craft landed on Mars and dashed even that hope. The Vikings searched for evidence of microscopic life but found none.

Though Mars may now be lifeless, the planet continues to spark our curiosity. Astronomers have been studying the Red Planet for centuries and have made Mars the target of a long list of space missions, with varying degrees of success. Despite this onslaught, what we know about Mars is far exceeded by what we don't know.

For example, although the previous Mariner and Viking missions to Mars were great successes, they left gaps in our knowledge of the planet. Previous missions looked at only 15 percent of the Martian surface with a resolution as good as 800 feet. Mars Observer will photograph the entire planet with that resolution and do so several times.

In addition, none of the previous orbiters saw the polar caps well — Mars Observer will orbit directly over both poles. And as fundamental a property as Mars' magnetic field has never been accurately measured — Mars Observer carries the most sensitive magnetometer ever carried there.

What we do know is that the inner planets, Mercury, Venus, Earth, and Mars, share a common heritage. They formed in the same region of the solar system at the same time, although each ended up as a very different world. With a diameter of 4,200 miles, Mars is larger than Mercury and Earth's Moon, but much smaller than Venus and Earth.

Red Planet Profile

- **Mars is 4,200 miles in diameter, roughly one-half the size of Earth.**
- **Despite its smaller size, Mars' lack of oceans means that Mars' land area is equal to Earth's.**
- **Mars rotates once every 24 hours 37 minutes.**
- **One Martian year lasts 687 Earth days, or about two Earth years.**
- **The surface gravity of Mars is 38% that of Earth.**
- **The atmospheric pressure is about 8 millibars (1/125 Earth's surface pressure).**
- **The atmosphere is 95% carbon dioxide, 2% to 3% nitrogen, 1% to 2% argon, and 0.1% to 0.4% oxygen.**
- **The surface temperature varies seasonally from –225° F to 60° F.**
- **The largest volcano on Mars, Olympus Mons, rises over 86,000 feet above the plains of Mars.**
- **11 spacecraft have successfully visited Mars since the first probe, Mariner 4, in 1964.**
- **The most successful missions were the U.S. Mariner 9 orbiter (1971) and the Viking 1 and 2 orbiters and landers (1976 to 1980).**
- **The last probes to Mars were the Soviet Phobos 1 and 2 craft launched in 1988. One failed en route, the other shortly after reaching Mars.**
- **Mars' next closest approach to Earth occurs on January 3, 1993, when it will be 58 million miles away.**

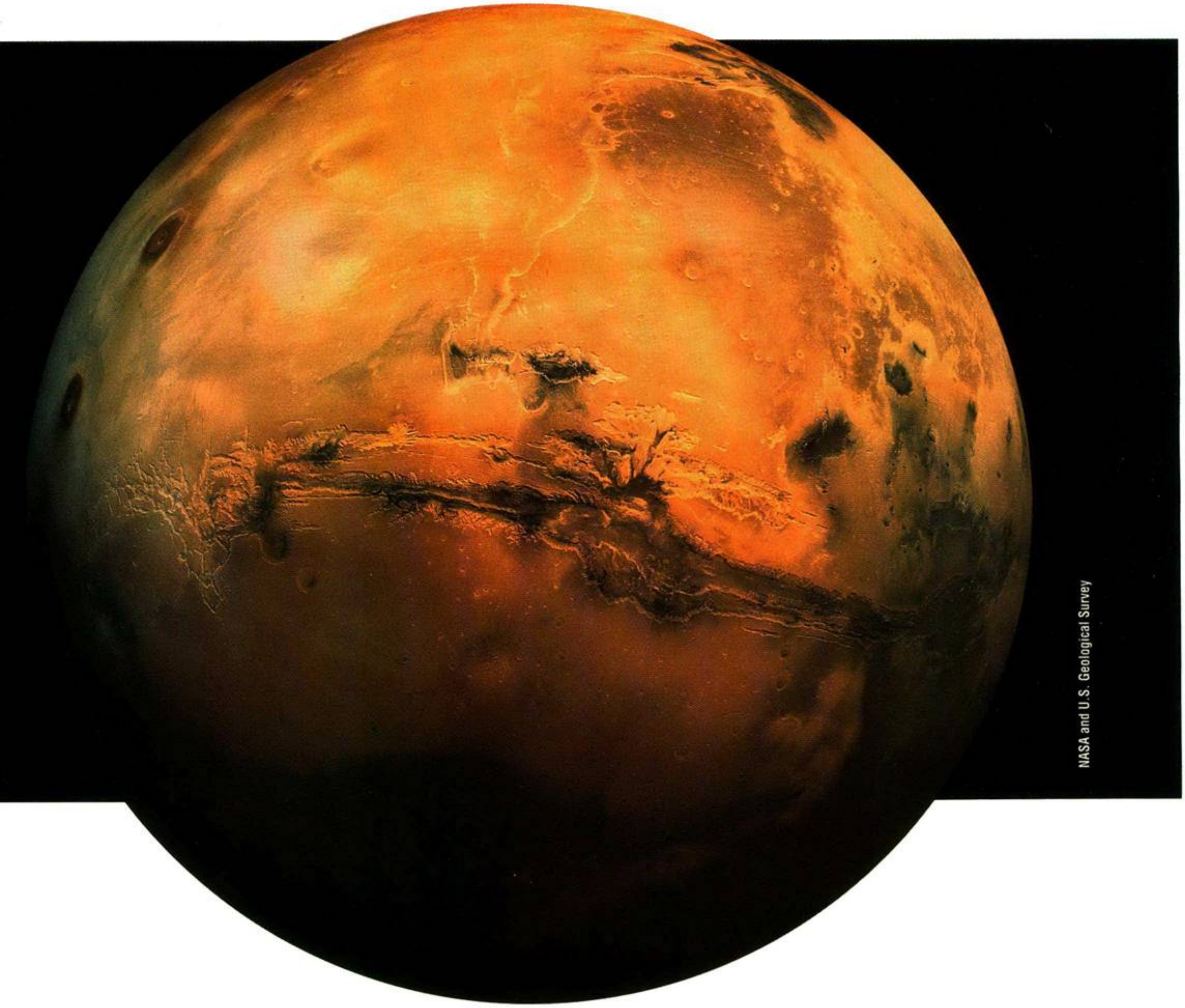
Despite its small size, Mars is similar to Earth in many ways. It turns on its axis in 24 hours and 37 minutes, making a Martian day slightly longer than an Earth day. Mars' axis is tilted over at an angle of 25°, compared to Earth's 23.5° inclination. As a result, Mars exhibits Earth-like seasonal changes. Summers turn to winters; winters end with the warming of spring, though even a warm day at most sites on Mars is no better than a balmy day in Antarctica.

Water, Water Everywhere

Mars also reminds us of Earth because its atmosphere has familiar-looking clouds and daily cycles of weather. But the atmosphere is thin. The pressure at the surface of Mars is only about 1 percent that of Earth (about as thin as the Earth's atmosphere 20 miles above the surface).

Carbon dioxide, a so-called "greenhouse gas," is the chief component of the Martian atmosphere. Scientists warn that a build-up of such gases may trigger a global warming on Earth, but ironically, just the opposite may have happened on Mars — its atmosphere may have been much more substantial in the past. With larger amounts of carbon dioxide in the air, Mars may have been subjected to a strong greenhouse effect in prehistoric times, giving the ancient planet a warmer and wetter climate than its current dry, arctic conditions.

The existence of water on Mars continues to stir scientific controversy. Today, Mars is almost totally dry. Liquid water cannot exist at the low pressures and temperatures found on the planet. Yet the Mariner and



NASA and U.S. Geological Survey

A NEW VIEW created with a mosaic of 102 Viking images reveals Mars' 1,200-mile-long canyon, Valles Marineris, and near the west limb (left), three of the planet's volcanoes. The mosaic is centered on a Martian longitude of 78°.

Viking missions of the 1970s found ample evidence that liquid water once flowed on Mars, cutting waterways and sinuous channels that twist and braid into multiple tributaries. But when? And where is the water today?

Some of the water could be locked in the permanent north polar cap, thought to be a reservoir of water ice as well as frozen carbon dioxide. Massive climate changes, triggered by as yet undetermined processes, may have released the carbon dioxide and water in the past, temporarily transforming Mars into a more Earth-like world.

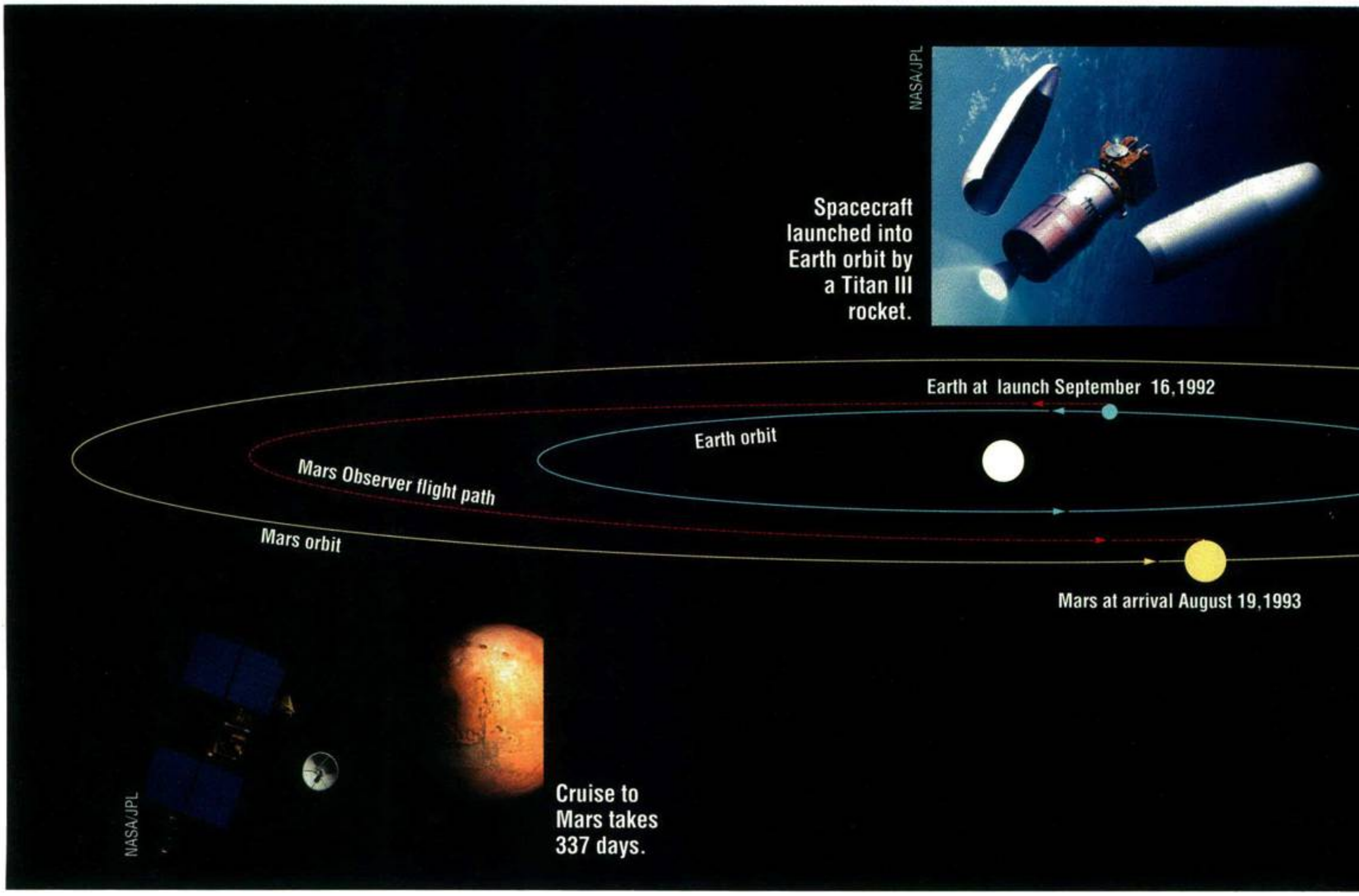
More water could be trapped under the soil as layers of permafrost. At times in the past this ice may have been melted by the intense heating of asteroid impacts, creating local flash floods.

Even today, however, what little water remains in the Martian atmosphere has noticeable effects, giving Mars distinct weather systems. At times, clouds, misty fogs, and winter frosts form alongside clouds and frosts made of carbon dioxide. The Viking orbiters glimpsed fog banks forming at dawn in the Martian valleys, while the landers photographed thin layers of frost accumulating around the craft's footpads on cold winter mornings.

Understanding the cycle of water on Mars, both through seasonal and long-term changes, is essential to understanding the geology and climate of Mars. And the biology. If Mars ever did have life, it may have arisen because Mars once had abundant water. The amount of water that remains today, and the ease with which it can be found and extracted, will certainly affect human exploration of the planet in the future. For these reasons, prospecting for water will be an important task for Mars Observer.

Gigabytes from Mars

To accomplish its tasks, Mars Observer carries a host of new technologies to the Red Planet. For example, the narrow-angle camera has the highest resolution of any imaging system flown to another planet. From Mars


NASA/JPL
Spacecraft launched into Earth orbit by a Titan III rocket.
Earth at launch September 16,1992
Earth orbit
Mars Observer flight path
Mars orbit
Mars at arrival August 19,1993
NASA/JPL
Cruise to Mars takes 337 days.

Observer's planned altitude just above the edge of the thin Martian atmosphere, this camera can resolve surface features as small as an automobile, though only over selected areas. Supplementing the narrow-angle camera, Mars Observer's two wide-angle cameras can produce a complete color image of the entire planet every day.

With gigabytes of data pouring back from the cameras and from the seven other science experiments, Mars Observer will return more science data over its two-year mission than all previous planetary missions combined — with the exception of Magellan now circling Venus.

Yet all this will be accomplished by a spacecraft made largely from off-the-shelf components. According to David Evans, Jet Propulsion Laboratory Project Manager for Mars Observer, "This craft capitalizes on the experience of several companies in building Earth-orbiting satellites." The design uses mechanical components and control electronics derived from utilitarian Earth satellites such as the Defense Meteorological Satellite Program (DMSP) craft, the TV and Infrared Observational Satellite (TIROS) weather satellites, and the SatCom series of communications satellites. New custom-made components on Mars Observer include all its experiments, as well as its steerable high-gain antenna, X-band radio, and propulsion system.

Unlike Galileo, Voyager, Viking, and most other interplanetary probes, Mars Observer has been built for NASA by a private contractor — General Electric Astro Space Division — under a fixed-price contract. In a unique arrangement, the profit GE realizes from the project is based on the amount of scientific data returned over the useful lifetime of the spacecraft.

Another innovation will allow project scientists to control their spacecraft experiments from their home institutions without being at Mission Control. Investigators can then receive their data through a computer network that links them to the Jet Propulsion Laboratory in Pasadena, the center of operations.

One-Year Journey, Two-Year Stay

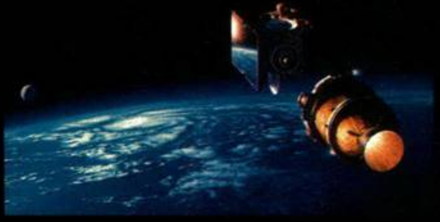
Launch of Mars Observer from the Cape Canaveral Air Force Station in Florida is set for September 16, 1992. But there is some leeway. To get to Mars the spacecraft must be on its way by October 6. Any later and it's a two-year wait until Earth and Mars are once again in the proper position.

Though once scheduled for launch aboard the shuttle, Mars Observer will now ride into space aboard a commercial Titan III rocket built by the Martin Marietta Corporation. After the Titan carries the spacecraft into Earth orbit, a second rocket booster, the Transfer Orbit Stage from the Orbital Sciences Corporation, fires for 150 seconds to break the spacecraft free of Earth's gravity and propel it on its way to Mars.

After performing its initial shove, the Transfer Stage separates, leaving Mars Observer on its own and coasting for 337 days. On August 19, 1993 (assuming a September 16 launch), Mars Observer reaches its destination. It fires its own rocket motor to slow it enough so that Mars' gravity can capture the spacecraft.

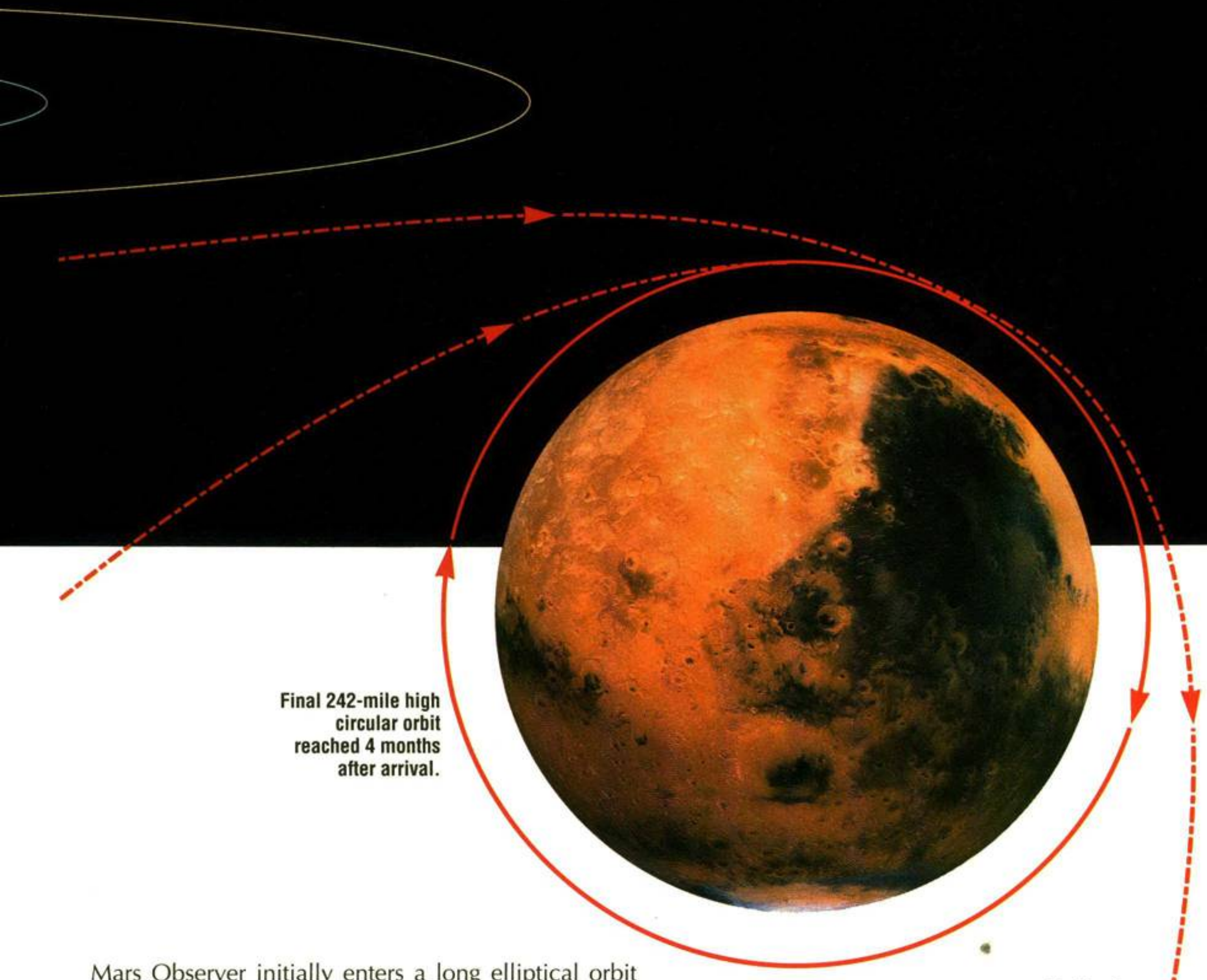
Flight facts

The trip to Mars begins this fall and lasts 11 months. When Mars Observer reaches its destination in 1993, it will first enter a long looping orbit over the poles. A 4-month-long process converts this to a low circular orbit.



Spacecraft injected into Mars trajectory by a Transfer Orbit Stage booster.

NASA/JPL



Final 242-mile high circular orbit reached 4 months after arrival.

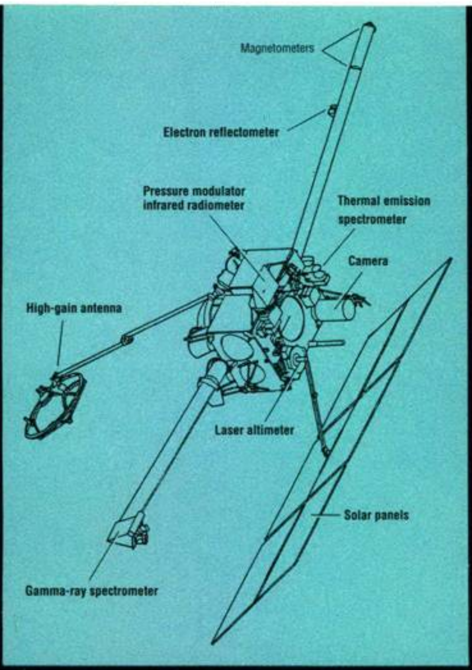
Craft enters initial elliptical orbit over the pole.

NASA and U.S. Geological Survey

Mars Observer initially enters a long elliptical orbit over the poles. Over the next 118 days, a series of seven rocket firings circularizes the orbit down to the planned altitude of 242 miles. By mid-December 1993, Mars Observer is ready to begin its two-year mapping.

Taking Inventory

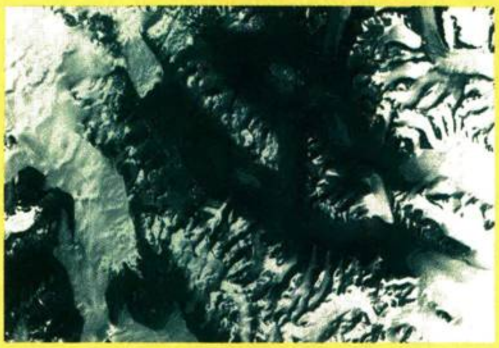
Unlike Viking, Mars Observer will focus not on biology but on geology and climate. As it orbits around Mars every 117 minutes, the spacecraft will act as a prospector, identifying the chemical elements present in the Martian soil and how they are organized into minerals and rocks. The instruments will also perform the role of weather satellite, determining how the Martian atmosphere varies with geographic location, altitude, and time. Mars Observer will measure the height of all the landforms on Mars, look for changes in the


Magnetometers
Electron reflectometer
Pressure modulator infrared radiometer
Thermal emission spectrometer
Camera
High-gain antenna
Laser altimeter
Solar panels
Gamma-ray spectrometer

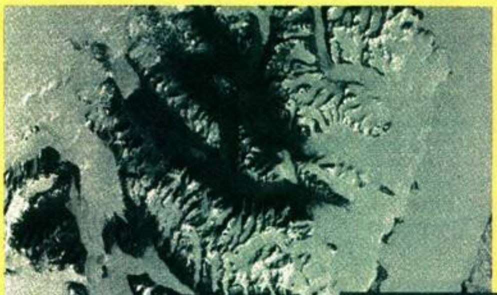
Spacecraft Synopsis

- Mars Observer was built by General Electric Astro Space Division.
- The spacecraft cost $500 million and is designed to last 5 years.
- Total weight on Earth (with fuel) is 5,600 pounds, the weight of two mid-sized automobiles.
- Spacecraft power is supplied by solar panels that can generate 1,130 watts.
- The camera system uses a 12 megabyte solid-state memory, the largest on any planetary mission to date.
- The wide-angle cameras resolve 242 meters per pixel; the narrow-angle camera resolves 1.4 meters per pixel.
- Data will be radioed to Earth at a maximum rate of 85,300 bits per second on a frequency in the X-band of 8.4 GHz.
- Maximum round-trip communication time between Earth and Mars during the mission will be 40 minutes.
- Each of three tape recorders on the spacecraft can record up to 48 hours of data for later playback.
- A complete mapping cycle around the planet will take 26 days, with 26 such mapping cycles possible during one Martian year.

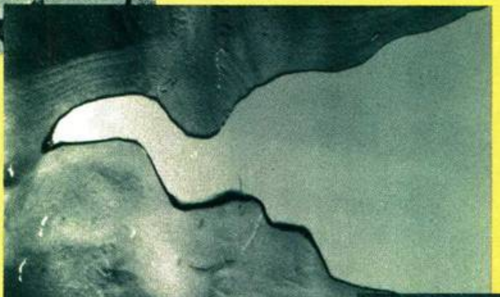
HOW SHARP will Mars Observer's images be? Views of the Lake Vanda region in Antarctica simulate the resolutions of the older Viking and new Mars Observer cameras. While the Mars Observer narrow-angle camera has very high resolution, only the craft's wide-angle cameras can map the entire planet.



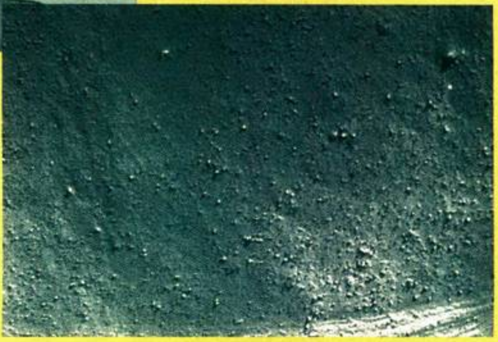
THE VIKING CAMERA was able to resolve details as small as 300 feet across but only of selected regions.



THE WIDE-ANGLE CAMERA of Mars Observer has a lower resolution than Viking's best images.

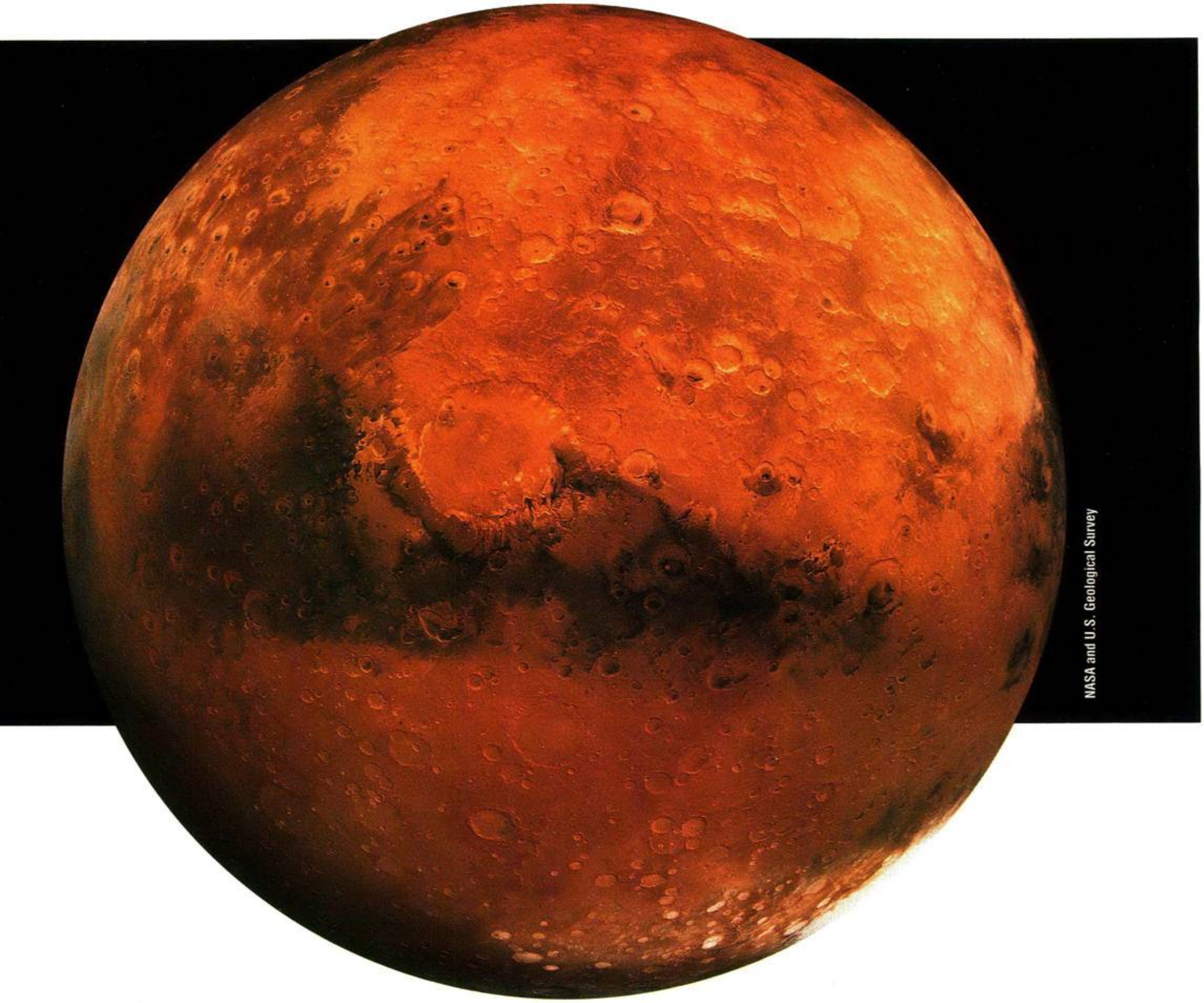


THE NARROW-ANGLE CAMERA can produce detailed close-ups, as in this view of the tip of Lake Vanda.



ENLARGING a section of the previous image reveals boulders 10 feet across.

Malin Space Science Systems/Mars Observer Camera



NASA and U.S. Geological Survey

surface features, and watch the polar caps as they evaporate and reform.

To complete its mapping, the spacecraft will circle the planet in an orbit that will take it over both poles. On the day side of the planet, Mars Observer will be traveling from the north to south. On each orbit it will cross the equator at about 2 p.m. local Mars time. It will always see the surface of Mars on the daylit side as it appears at mid-afternoon. This "Sun-synchronous" orbit puts the Sun at a standard angle above the horizon in each image, and the mid-afternoon crossing provides good shadows to make surface features stand out.

Mars Observer will spend one Martian year — the equivalent of two Earth years, or 687 Earth days — mapping the planet. This mission length allows scientists to study the planet through its four seasons, creating a complete inventory of Mars' surface properties and weather patterns.

The Eyes of Mars Observer

Mars Observer has eight instruments for gathering its global inventory. Some, such as the magnetometers and gamma-ray detector, are mounted on outrigger booms. Most are on the bottom of the main spacecraft bus, a box roughly the size and mass of two mid-sized automobiles.

The complement of instruments gives Mars Observer eyes to see across the entire spectrum. The gamma-ray spectrometer measures the intensity of high-energy photons created by the natural decay of radioactive elements on the surface or by cosmic rays' colliding with the atmosphere and surface. The spectrum of gamma rays tells scientists what chemical elements are present on the surface.

To further identify surface rocks as well as map the distribution of ices, scientists will use the thermal emission spectrometer, an instrument sensitive to the infrared band of the spectrum. The instrument can also

DARK MARKINGS are the features visible from Earth. They are areas blown free of Mars' pervasive red dust by prevailing winds. The dark streak in this view is Sabaeus Sinus at longitude 340°. The white area is frost over the Hellas basin.

Martian Mysteries

Mars Observer is designed to answer many outstanding mysteries about the Red Planet:

- **What is the Martian surface made of?**
- **How much water is there on Mars?**
- **Where is the water on Mars? Can it be tapped?**
- **What role did water have in shaping the surface?**
- **What triggers the global dust storms of Mars?**
- **What type of magnetic field does Mars have?**
- **Is the interior of Mars molten?**
- **What weather patterns does Mars have?**
- **How does the weather change over a year?**
- **What creates the layered structures of the polar caps?**
- **How has the Martian climate changed over the planet's history?**
- **What can climate changes on Mars tell us about Earth's history?**
- **What are the best sites for future manned and unmanned landing missions?**

- **Yes, but what about that notorious face on Mars?**

Despite the resolving power of Mars Observer's narrow-angle camera, it may not be able to photograph the so-called "face," a rock formation photographed by Viking that resembles an upturned human face. The narrow-angle camera cannot be pointed precisely at targets of interest — the camera is fixed to the bottom of the spacecraft to point only at the surface that lies directly below. Taking a picture of a specific site with this camera requires waiting weeks or months for the orbit of Mars Observer to carry it over the site and then starting an exposure at the right time, with the hope that the calculations of the spacecraft position and target location were good enough that your target ended up in the camera's very narrow field of view during the exposure. Because of this hit-or-miss framing, Mars Observer may never get a close-up shot of the geologic feature.

monitor the growth and decay of the Martian polar caps and any dust storms that whip up while Mars Observer is watching.

Mapping Mars wouldn't be complete without the ability to create a detailed contour map of the surface. To do that, Mars Observer's laser altimeter uses a very short pulse of laser light to measure the distance from the spacecraft to the surface with a precision of several meters. This gives a measure of the height of all the surface features on Mars, something still poorly known.

To map the atmosphere, a device called the pressure modulator infrared radiometer looks off to the horizon as well as beneath the spacecraft. It can measure the temperature, pressure, water vapor content, and dust content of the air, creating a profile of the atmosphere from the surface up to an altitude of 50 miles.

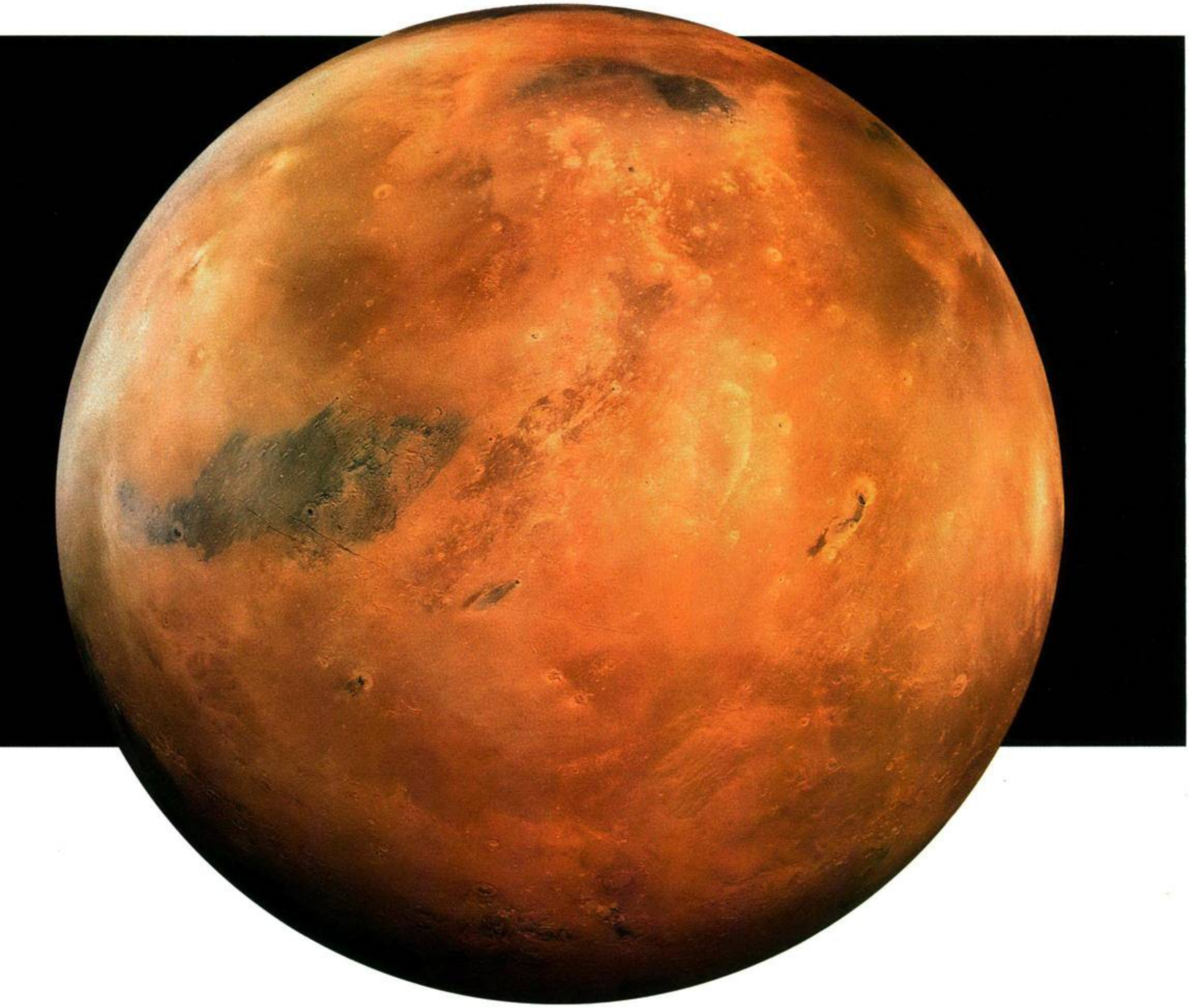
Mars is the only planet in the solar system, aside from Pluto, whose magnetic field has not yet been measured. The magnetometer and electron reflectometer will map Mars' magnetic field and determine whether Mars has an active fluid core.

An important experiment has no dedicated device on board the spacecraft. The radio science investigation will monitor the radio beams from the spacecraft's telecommunications system each time the spacecraft passes behind the planet or reappears on the opposite side. (There are eight to ten such events each day.) Measuring how the atmosphere distorts the radio beam provides a probe of the structure, pressure, and temperature of the atmosphere in greater detail than any other Mars Observer experiment.

As the spacecraft orbits Mars, variations in the planet's gravitational field will cause Mars Observer to speed up or slow down. The velocity changes cause subtle fluctuations in the frequency of its transmitted signals, an effect scientists will exploit to map the gravitational field of Mars.

Finally, Mars Observer's camera: Its wide-angle optics use a pair of 11mm-focal-length fisheye lenses, one for taking blue-light pictures, the other for red-light images. Together, they can take color images of Mars that extend from horizon to horizon. Like the weather satellite photos of Earth we see on the nightly news, these global views are good for watching the changing weather patterns of Mars. At the distant horizon, the resolution of these images is 4.5 miles. But underneath the spacecraft, the wide-angle optics can resolve details as small as 800 feet across. This wide-angle system will be the workhorse mapping camera of Mars Observer.

The narrow-angle camera uses a separate set of optics — in this case a Ritchey-Chretien telescope with a 14-inch-diameter f/10 mirror. As in the wide-angle system, the light-sensitive detector is an electronic chip called a charge-coupled device (CCD). However, this CCD camera cannot take snapshots of an entire scene. It consists of 2,048 light-sensitive diodes arranged in a single row. The camera builds up image frames by allowing the motion of the spacecraft to sweep the row of diodes across a scene during the exposure, like a facsimile machine scanning a page. Using this technique, Mars Observer can take high-resolution images of selected areas that are always 1.7 miles wide (the field of view of the chip-and-telescope combination) but can extend for tens of miles along the path of the spacecraft (the length



NASA and U.S. Geological Survey

IT TOOK SEVERAL YEARS to piece together Mars images like this one from dozens of Viking photos. By contrast, Mars Observer will produce a color view of the entire planet every day. This image shows the Cerberus area (longitude 190°).

depending on how much computer memory is available to store the digital image). Within that swath, the camera can reveal objects less than 10 feet across.

Beyond Mars Observer

As Mars Observer ends its main mission in late 1995, the spacecraft will perform a new role, that of radio relay for the next spacecraft to Mars — the International Mars '94 mission. Originally a Soviet venture, the Mars '94 probe is now a Russian project in cooperation with many European and former Eastern bloc countries. Mars '94 consists of a single orbiter that will reach Mars in 1995. Just before arrival, the craft will release two small surface penetrators and two small landers. Mars Observer will receive the signals from the four craft and relay them to Earth — signals that will include images taken during the descent and from the surface itself.

If Mars Oberver is still active two years later, it will perform the same relay service for Mars '96, a Russian/European probe that will carry a rover and a balloon.

That same year, 1996, could see NASA's next Mars mission, called MESUR Pathfinder, on its way as well. MESUR is the Mars Environmental Survey, a 10-year program that consists of a single lander equipped with a microrover launched in 1996 — the Pathfinder — followed by 16 minilanders in four separate launches between 1999 and 2003.

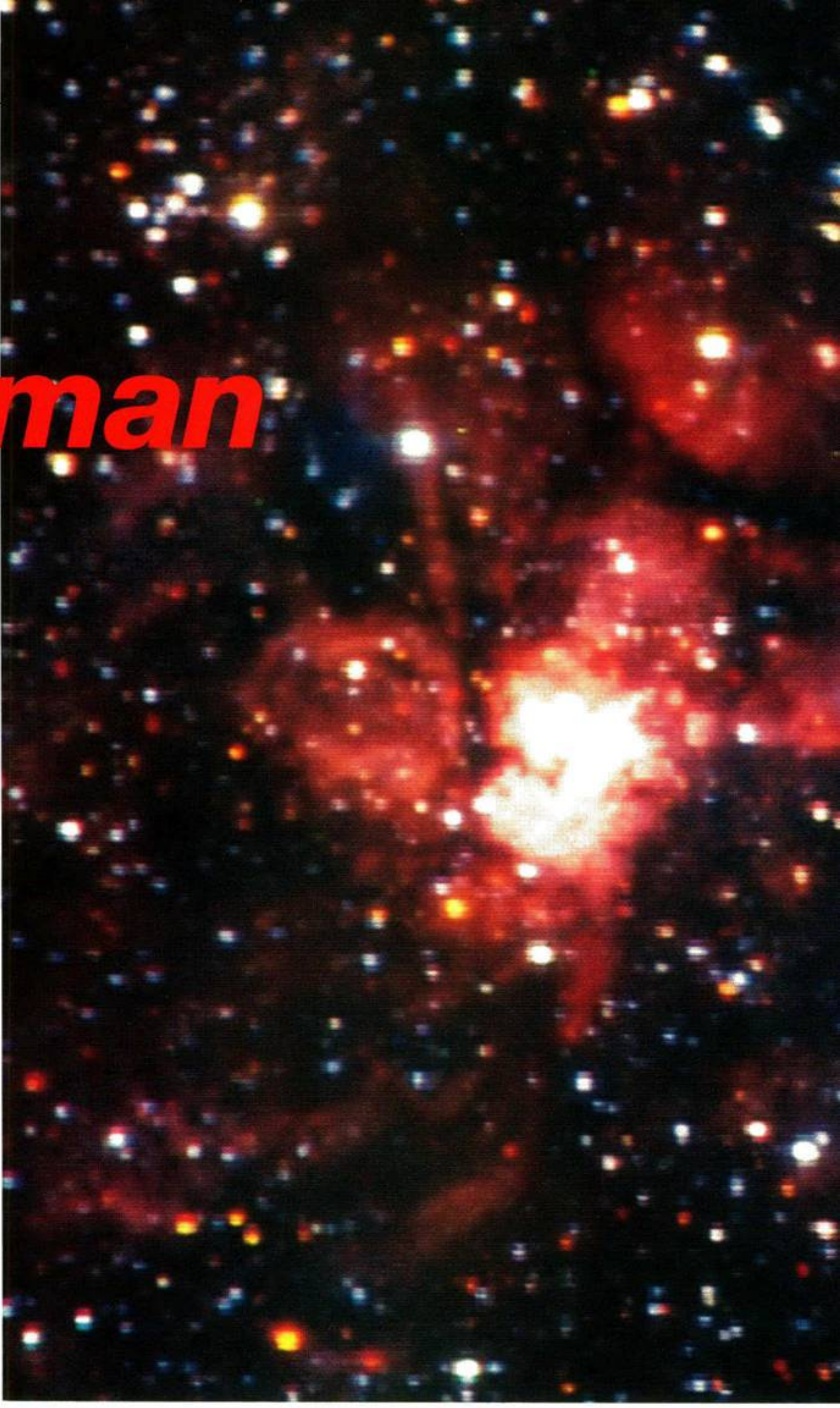
The culmination of the new focus on Mars exploration will be the first footfall of human beings on another planet. If and when people do walk on Mars in the 21st century, it will be the result of a dedicated program of exploration that begins this month with the launch of Mars Observer. □

Diane Ainsworth is a senior staff writer at the Jet Propulsion Laboratory in Pasadena, California.

The Huntsman Nebula

One of the Milky Way's largest star-forming regions comes to life through the vision of infrared cameras.

by David Allen & Vikki Meadows



All photos ©Anglo-Australian Telescope Board

MASSIVE STARS FORM in the Huntsman Nebula, located about 12,000 light-years from Earth. An infrared view (above) shows the true extent of the ionized-gas cloud. Dust shields the nebula from view in a visible-light image (right).

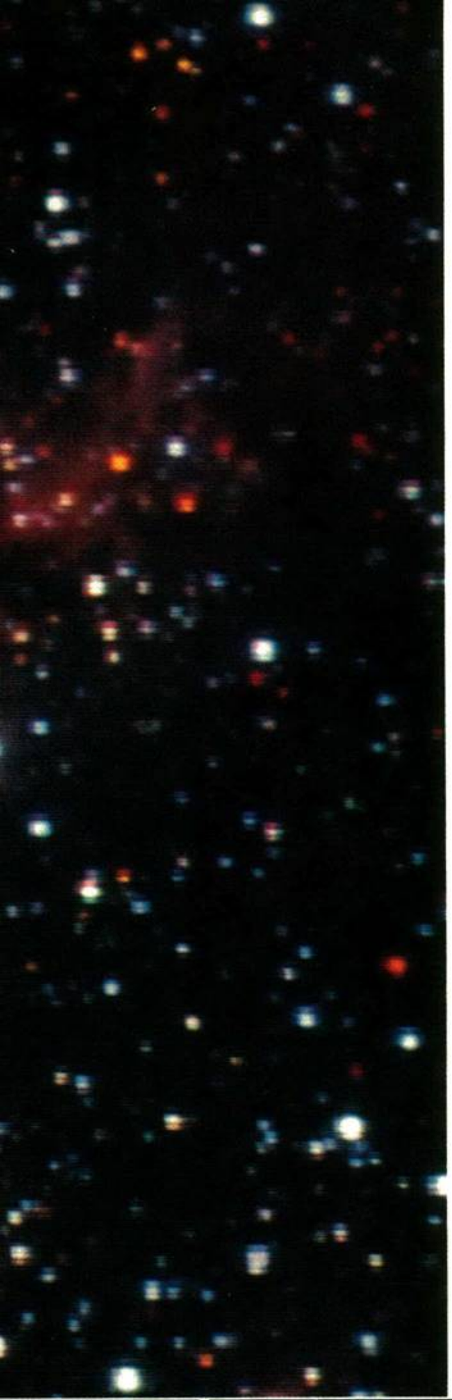
Late one night in February 1991 while we were observing in the infrared at the 3.9-meter Anglo-Australian Telescope (AAT), someone suggested we look at a large cloud of ionized gas that radio astronomers call G333.6 –0.2. This nebula is located about 12,000 light-years away in the constellation Norma. Visible-light images of the nebula are unremarkable, but our infrared images show it to be striking and hint at the history of the formation of the massive stars inside.

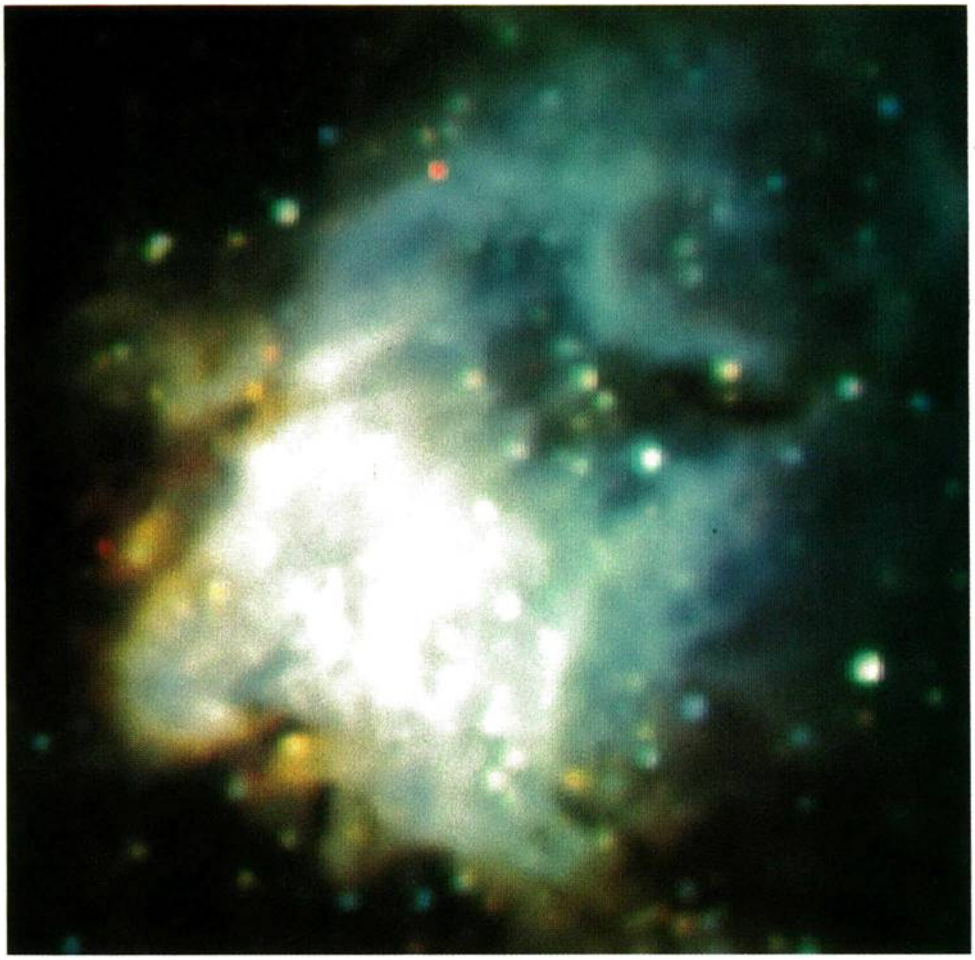
We were using a new infrared camera called IRIS that a team of nearly 20 people at the Anglo-Australian Observatory had developed during the previous year. This camera uses an infrared sensitive electronic chip that measures 128 pixels on a side. The wide-field mode of the camera showed the nebula to be large, bright, and structured. The central region of the nebula appears extremely bright, possibly even brighter than the Orion Nebula. Several loops rise from the central region. The brightest of these loops, along with the hourglass shape of the central region, remind us of a large spider.

We returned to look at the nebula in July 1991. Using IRIS's high-resolution mode, we obtained images of the nebula at three different infrared wavelengths. Assigning each of the wavelengths a different color (blue, green, and red), we combined the images to produce a false-color image of the nebula, as if we had infrared color vision.

Normal ionized-gas clouds would appear blue in our false-color scheme. But dust in front of the spidery nebula absorbs or scatters the shorter wavelengths of light, making the nebula appear reddish.

The infrared view shows the true size of the gas cloud and details that are invisible at optical wavelengths. Without the intervening dust that





A WARM GLOW COLORS the Huntsman Nebula red, but the same false-color technique painted another nebula (RCW 38, above) in bluish tints. The reason for the difference is that RCW 38 has much less dust lying between it and Earth.

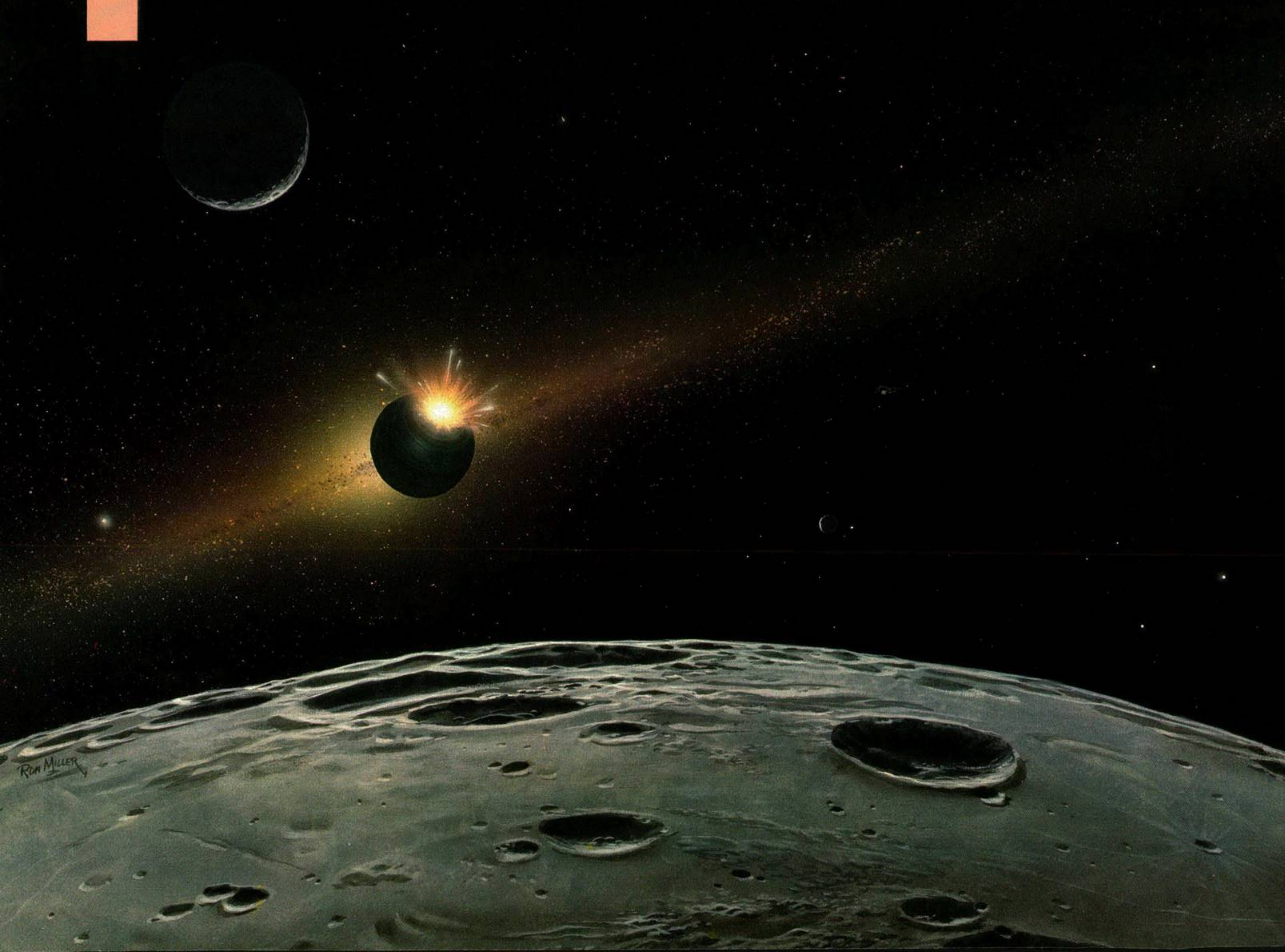
blocks visible light from reaching us, this would be one of the most spectacular nebulae in the sky.

Finding a name for this object proved easy. During July, spiders come inside the AAT dome to escape the Southern Hemisphere winter. Huntsman spiders are the most common and are known to travel across the observatory's computer monitors. A good-sized Huntsman can straddle a saucer. The spiders are not particularly hairy (as you might expect of a large spider) and their bodies look similar to the central region of G333.6–0.2, so we named it the Huntsman Nebula.

The Huntsman is one of the major regions in our Galaxy that is presently forming massive stars. The loops show that hot, young stars have blown bubbles in the gas cloud. These loops suggest that the Huntsman is older than the Orion Nebula and more similar in age to the 30 Doradus region in the Large Magellanic Cloud.

The hot stars exciting the hydrogen gas in the Huntsman Nebula are cool — 30,000 to 35,000 kelvins — compared with the stars that excite most emission nebulae. Apparently the hottest stars have already become supernovae. The bubbles in the gas cloud may, in fact, have been created by these supernovae. But whether supernovae or stellar winds from hot, young stars created the nebula's loops and bubbles, the new infrared views have brought a better understanding of this ionized-gas cloud and the formation of massive stars inside. □

David Allen is the IRIS project scientist at the Anglo-Australian Observatory. Vikki Meadows is a graduate student at Sydney University, using IRIS to gather data for her doctoral dissertation.


Ron Miller

Where has Pluto's family gone?

Hundreds of icy Pluto-like planets may have roamed the outer solar system before being ejected into the vast comet cloud.

by Alan Stern

Textbooks tell us two main groups of planets make up the solar system. One group consists of four dense, rocky, terrestrial planets that circle in tight orbits tucked within a distance less than twice Earth's distance from the Sun. The other consists of four gargantuan, low-density gas giants that orbit between 5 and 30 times Earth's distance from the Sun. Just beyond the last of the gas giants lies icy Pluto. This tiny world traces an unusually inclined and eccentric orbit and, at 0.2 percent of Earth's mass, it is significantly smaller than any of the other eight planets.

Pluto's size and orbit are unlike those of any other planet, suggesting that it is a misfit. While the origin of the other planets is relatively clear, it is difficult to explain how this single little world developed at the ragged edge of the planetary system. Pluto appears to be a loose end that challenges our conventional view of the solar system's architecture.

One theory explaining the formation of Pluto suggests that the planet is an escaped satellite of one of the giant planets. Another suggests Pluto could have formed as the by-product of a collision that occurred during the construction of Jupiter, Saturn, Uranus, and Neptune from smaller icy bodies. Or is it something else?

Formation of the Planets

Over the last several decades astronomers have established a standard model for the origin of the planets. This model states that the solar system started when an interstellar gas cloud collapsed gravitationally. The continued collapse of the cloud heated the central portion of the gas until nuclear fires were kindled, creating the Sun.

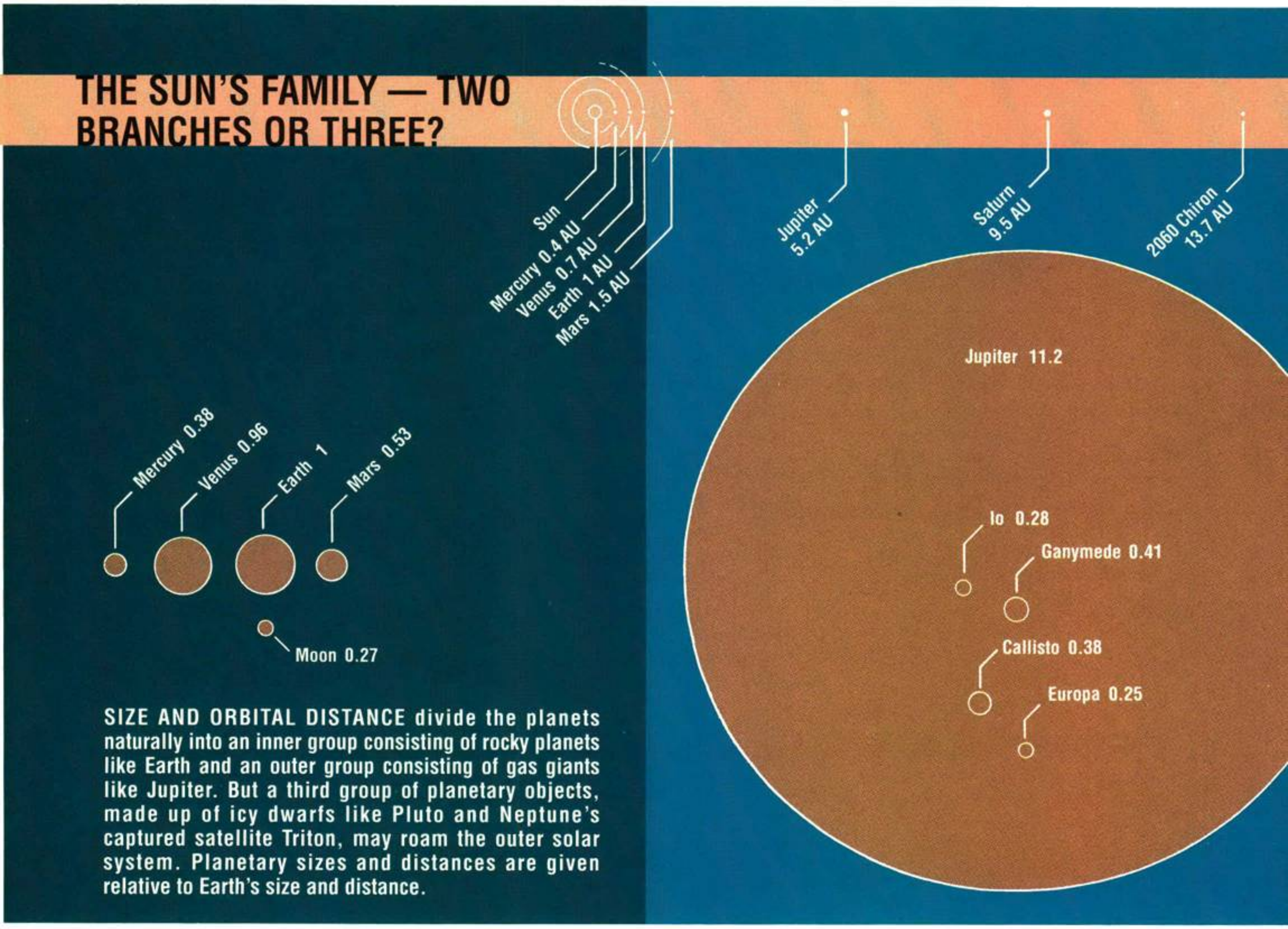
The spinning of this gas cloud caused dust and gas left over from the formation of the Sun to form a disk. In-falling interstellar dust grains — and dust grains that formed in the nebula itself — suffered a frictional drag from gas particles in the nebula that caused them to settle down to a narrow plane. This plane lay at the center of the disk formed by gas particles and was perhaps tens of thousands of times thinner.

The dust grains were composed primarily of silicon- and carbon-based materials, and water, methane, and carbon monoxide ices. Where the density of grains was high enough, collisions frequently took place between particles in nearby orbits. These gentle collisions caused the grains to grow. Gravitational instabilities in the dust disk accelerated this growth, which caused groups of growing grains to condense and form kilometer-sized "planetesimals."

From the study of very young solar-type stars, called T Tauri stars, it's clear that the formation of dust and gas disks around stars is common. But the T Tauris also have strong stellar winds that quickly dissipate their dust and gas disks. Observations of hundreds of T Tauri stars in the Orion and Taurus-Auriga stellar nurseries indicate that every

Ron Miller

THE SUN'S FAMILY — TWO BRANCHES OR THREE?



SIZE AND ORBITAL DISTANCE divide the planets naturally into an inner group consisting of rocky planets like Earth and an outer group consisting of gas giants like Jupiter. But a third group of planetary objects, made up of icy dwarfs like Pluto and Neptune's captured satellite Triton, may roam the outer solar system. Planetary sizes and distances are given relative to Earth's size and distance.

solarlike T Tauri star blows its disk away after 1 to 10 million years of nuclear burning.

The tiny dust grains and pebbles in the disk are highly susceptible to drag from these winds. Unless the small particles can assemble into larger, less drag-susceptible objects, they will be blown out of orbit around the star and back into interstellar space. Fortunately, computer simulations of planetesimal growth in the solar nebula indicate that drag-resistant, kilometer-sized planetesimals can form before the onset of the T Tauri wind.

Like the tiny dust grains they grew out of, planetesimals collide while in orbit around their star. Oftentimes, the collisions are gentle enough that the planetesimals grow in size. This process, known as planetesimal accretion, builds up larger and larger bodies until a few of the fastest-growing planetesimals exceed a critical mass, at which point their gravitational attraction becomes a significant aid to growth.

Then these bodies can attract other planetesimals in neighboring orbits that would not otherwise collide. Because each collision resulting in accretion adds more mass to these bodies, the process accelerates rapidly, creating runaway growth. In this runaway process, the first objects to reach critical mass grow faster and faster until all the material in the nebula eventually accretes into planets or is gravitationally ejected to distant orbits by near misses with the growing giant planets.

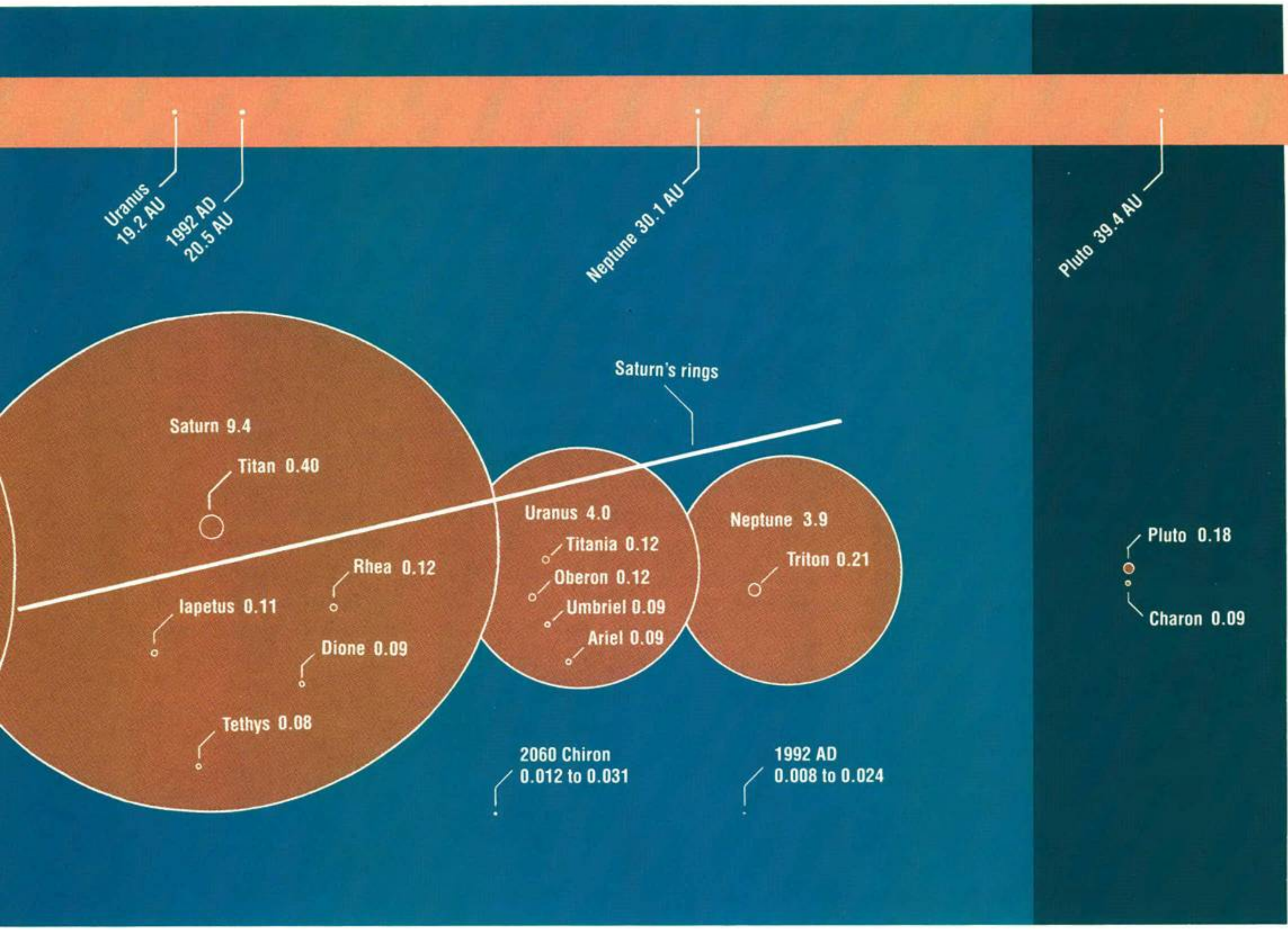
Astronomers believe such ejections populated the distant Oort cloud with 100 billion icy planetesimals, more commonly called comets. Once accretion and ejection exhaust the supply of planetesimals, the accretion phase of planetary formation is complete.

Some evidence for this accretion process comes from chemical studies of the Moon that indicate the Moon was formed most likely as the result of a collision between a Mars-sized body and young Earth. Other testimony for the accretion process comes from the differing compositions of the asteroids and planets, the atmospheric composition of the terrestrial planets, and the ubiquitous cratering seen on the Moon, Mercury, and the satellites of the giant planets. Craters ranging in diameter from tens to hundreds of kilometers scar the airless planets and satellites. Many of these craters were formed by the final clearing of planetesimals as the accretion phase drew to a close.

An Unlikely Bump in the Dark

Given this general view of planetary formation, it's not too difficult to imagine Pluto simply as a lone relic embryo of planetary formation that was fortuitously ejected to a not too distant yet safe orbit, where it has remained ever since. Indeed, Pluto's orbit remains protected because the orbits of Pluto and Neptune are gravitationally locked in a state called resonance that prevents Pluto from approaching closer to Neptune than 17 astronomical units. (One astronomical unit, or AU, is the average distance between the Sun and Earth.)

So why the fuss? Why is Pluto's existence so hard to reconcile with



ASTRONOMY: Lee Vande Visse

the architecture of the solar system? The problem is Charon, Pluto's only moon, which was discovered in 1978 by James Christy of the U.S. Naval Observatory.

A series of mutual eclipses of the planet and its satellite from 1985 to 1990 revealed that Pluto and Charon are a highly unusual pair. Both Pluto and Charon have low densities and icy surfaces, which indicates that they formed in the cool, outer part of the solar system. While most planets are much larger than their satellites (see the illustration above), Charon is half the size of Pluto and about 20 percent of Pluto's mass. Even the Earth-Moon system, sometimes called a double planet, is nowhere near as similar in size and mass, with the Moon being about one-quarter the size of Earth and having only about 1 percent of Earth's mass.

No known process could cause Pluto to form such a comparatively large satellite during accretion. Further, the angular momentum of the Pluto-Charon pair rules out the formation of Charon by the splitting of a rapidly rotating proto-Pluto into one large and one small piece.

Instead it appears Pluto and Charon formed independently and then collided, forming the present Pluto-Charon pair. This scenario, first suggested in 1984 by Bill McKinnon of Washington University in St. Louis, is supported by evidence that the other hypotheses cannot easily explain. This includes the similar masses of Pluto and Charon, the 17° tilt of Pluto's orbit, the large eccentricity of Pluto's orbit, and the fact that both Pluto and Charon rotate on their sides as Uranus does, with their rotation axes lying in the plane of their orbit. Pluto's orbital eccentricity may be related to the force of the collision between Pluto and Charon. Most planetary scientists now favor this model.

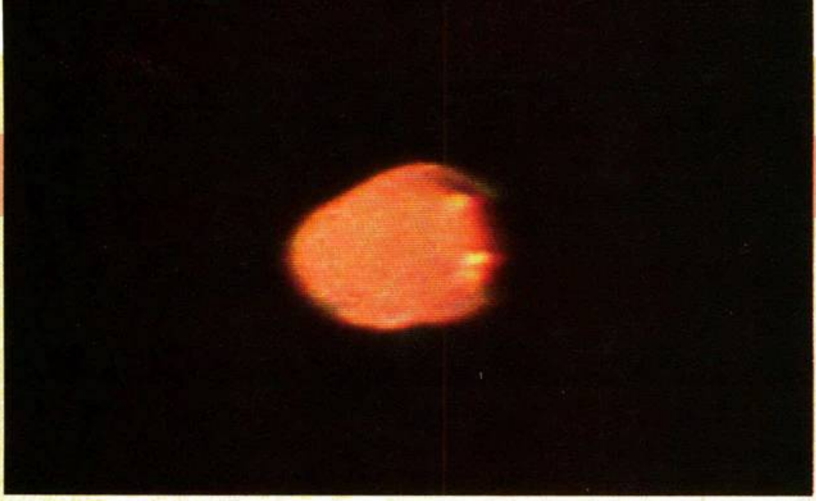
Despite its present popularity, the collision theory does face one difficult hurdle. It is highly unlikely that two small planets would experience such a collision in the vastness of the outer solar system. Some of my recent research points out the very low probability of such a collision. Using numerical calculations, I demonstrated that if Pluto and Charon started in separate orbits in the outer solar system, they would not, in all likelihood, collide, even over the age of the solar system.

To compute the collision probability of Pluto and Charon, we use the same principles used by 19th-century physicists to model the motions of molecules in a gas. This "particle-in-a-box" approach estimates the probability that two or more particles in a container of known volume will collide with one another within a specified period of time. For the Pluto-Charon collision, this standard approach requires knowing only three things: their sizes, the volume of space in which Pluto and Charon orbit, and the relative velocities of the pre-collision orbits.

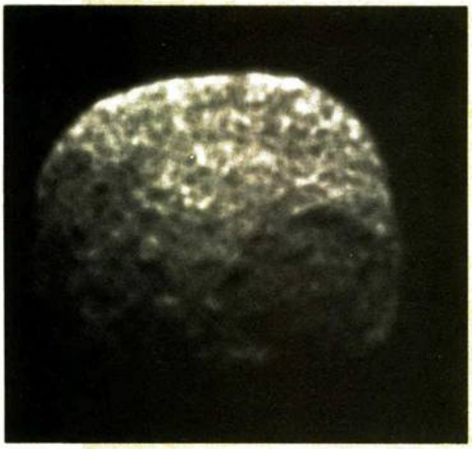
Over a range of reasonable values for these variables, the probability of Pluto's physically running into Charon is negligible — less than one in a million over the age of the solar system. Another way of saying this is that Pluto and Charon, orbiting alone in the outer solar system, would not

Ice Dwarfs: minor planets or major rocks?

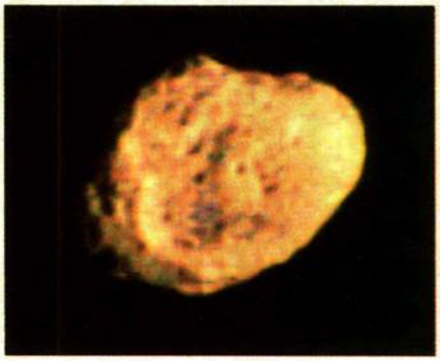
All photos pages 44-47 by NASA



Amalthea



Proteus



Hyperion

The small sizes of the ice dwarfs raise the question as to whether these bodies are true planets or not. Obtaining an answer is not easy because no official definition of what constitutes a planet exists. But we can construct a good working definition.

To classify a body as a planet, it is reasonable to ask that it satisfy three criteria. First, the object must directly orbit the Sun rather than some other body, as a satellite does.

Next, the body must be massive

have collided in 4.5 billion years unless the most extraordinary of coincidences took place.

An attractive solution to Pluto and Charon's unlikely collision is to increase the number of small, Pluto-like planets swarming about the outer solar system during the era when Uranus and Neptune formed.

With many more bodies orbiting in the same region, the collision probabilities increase rapidly as the square of the number of bodies. The one in a million chance stated above increases to about one in a hundred for 100 bodies. To make the collision between Pluto and Charon likely (a 50/50 chance) requires roughly 1,000 Pluto-like bodies residing in the 20 to 30 AU region, even if we assume the collision took place anytime during the 4.5-billion-year history of the solar system. (But collisions are still rare because the average distance between these bodies is roughly 1 AU.) Depending upon uncertainties in the original orbital distribution of these bodies and the time scale during which they were present in the Uranus-to-Neptune zone, the actual population of small, icy planets implied by the presence of the Pluto-Charon binary could have been as small as a few hundred or as large as ten thousand. Although this range of uncertainty is large, the point remains that many more bodies than the ones we see today were required to make the Pluto-Charon collision likely at all.

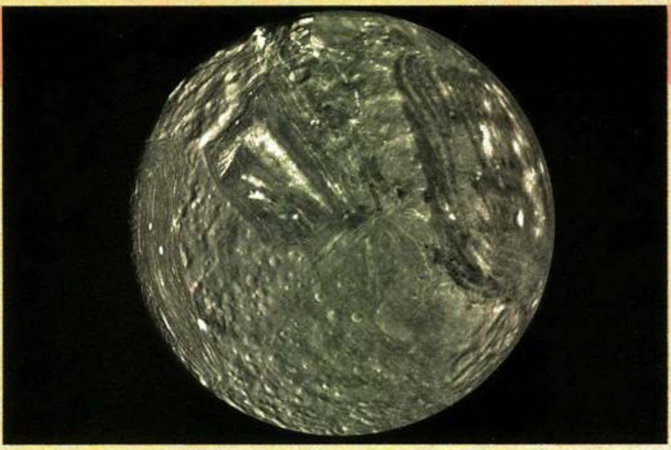
It's certainly a radical departure from the standard view of solar system architecture to expect that in addition to the nine known planets, hundreds or thousands of icy planets 1,000 to 3,000 km in diameter also formed. But the case for a population of small icy planets, or "ice dwarfs," is not at odds with other important constraints on the formation of the outer solar system.

One such constraint is the total amount of material available in the region where Neptune and Uranus formed. Recent simulations of planetary formation in the outer solar system indicate that the formation process was not efficient. As much as 100 Earth masses of material probably resided in the Uranus-to-Neptune zone when accretion began, but only about 30 Earth masses of material altogether went into Uranus and Neptune. Because Pluto-like ice dwarfs are small and not very dense, even 1,000 of them would add up to only 2 Earth masses of material. Since these formation models indicate that 30 to 70 Earth masses of excess material were ejected from the region, it is not unreasonable to expect that ice dwarfs made up a few percent of the ejected objects.

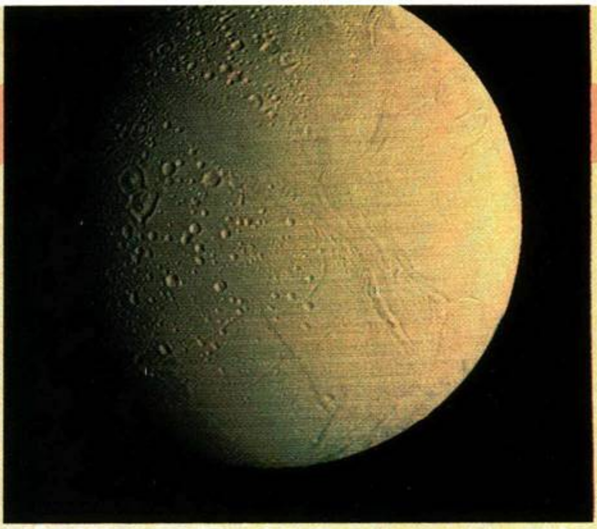
More Roads to Rome

Based only on the low probability of a collision forming the Pluto-Charon pair, the case for hundreds or thousands of small icy planets is intriguing, but hardly compelling. What makes the ice dwarf hypothesis more convincing are the other lines of evidence pointing to the same conclusion.

The first of these concerns Triton, Neptune's largest satellite. Triton is only slightly larger than Pluto. It orbits Neptune in a retrograde — clockwise, as seen from north of the planet, rather than counterclock-



Miranda



Enceladus

enough to become round owing to the force of its own gravity. This condition requires that the object's mass rather than its composition control the body's shape. Roundness due to mass is the hallmark of a planet. A quick check of Voyager images of small satellites shows that very small (10 to 100 kilometers in diameter) satellites have a variety of irregular shapes, making them little more than orbiting rocks. Similarly, Voyager images of icy satellites also show that bodies become increasingly round as self-gravity begins to play a role. Calculations based upon mass and material properties show that the transition from an irregularly shaped to a gravitationally rounded body takes place for objects 200 to 400 km in diameter. The exact size depends upon the object's composition and how fast it rotates. Voyager images of satellites throughout the outer solar system support these calculations.

The final criterion for planethood is that a body cannot be so large that it can ignite nuclear fires in its interior and thus become a star.

This three-point test for planets isn't perfect, but it does serve as a guide as to which bodies may be planets. It limits the high and low ends of the size or mass for planetary bodies. By these criteria, meteors and most asteroids fail to qualify as planets. But the largest asteroids do qualify as planets, as do the ice dwarfs of 1,000- to 3,000-km diameter (Charon, Pluto, Triton, and their suspected brethren).

wise as for most satellites — orbit, which is recognized as the signature of a capture from a solar orbit.

Planetary scientists, including McKinnon and Caltech's Peter Goldreich, have studied different methods by which Neptune could have captured Triton. Possible capture scenarios include direct orbital capture, capture assisted by gas drag in Neptune's atmosphere or the proto-Neptune nebula, and capture following a collision between a Sun-orbiting Triton and a primordial satellite of Neptune. In each case, computer simulations show capture to be extremely improbable. Neptune's capture of a Triton orbiting the Sun only becomes probable if several hundred "Tritons" orbit the Sun near 30 AU.

Even more evidence for the formation and former presence of a plethora of icy primordial planets in distant heliocentric orbits is provided by the tilts of Uranus and Neptune. Uranus' rotation axis is tilted 98° to its orbital plane, so its poles lie almost along its orbit. Neptune's rotation axis is tilted almost 30°. Alastair Cameron and his co-workers at the Harvard-Smithsonian Center for Astrophysics have found that large tilts imply collisions with other planet-sized bodies toward the end of the planet's accretion phase. To produce such large tilts, the impactors need masses between 0.2 and 5 Earth masses, depending upon the impact speed and the direction of the blow. Studies of the collision probabilities estimate that about 50 such planetary bodies would be required to make such collisions likely. Although these bodies are much larger than the ice dwarfs predicted by the Pluto-Charon collision and Triton's capture, they do indicate that many objects larger than the tiny, cometlike planetesimals formed in the early outer solar system.

In such a scenario, Pluto, Charon, and Triton are simply the relics of a once-larger population of small planets. Pluto, Charon, and Triton are still in the 20 to 30 AU zone because they are in protected dynamical niches, free from the possibility of accretion or ejection. Pluto and Charon are protected because of the resonance with Neptune, which keeps the pair from approaching close to Neptune. Triton has been protected from accretion or ejection because it is in orbit about Neptune.

It's interesting to note, however, that Triton's retrograde orbit is predicted to decay in several billion years, at which time it will crash into Neptune and merge with it. If we were living after that event rather than now, the clue that Triton provides wouldn't be known to us.

Taking each clue in isolation, we can reasonably conclude that the formation of the Pluto-Charon binary, the capture of Triton, the tilting of Uranus, or the tilting of Neptune could have occurred by itself, though each had only a small chance. But the combined probability that seven objects could cause four events would be less than one in a million billion (one in 10^{15}) over the age of the solar system (the seven objects being Uranus, Neptune, Pluto, Triton, Charon, and the two rogue objects to tilt Uranus and Neptune, and the four events being the creation of the Pluto-Charon binary, Triton's capture, and the tiltings of Uranus and Neptune). This is similar to the probability of your reaching into a hundred thousand tons of beach sand and, on the first try, pulling out the one hidden grain that was painted purple. With the various clues seen together, one finds a compelling case that each of the three outer planets gives independent evidence of events best explained by a population of several hundred to several thousand ice dwarfs.

Where the Dwarfs Are

One of the most interesting aspects of the ice dwarf theory is that the evidence for their formation is contained in a set of clues that have been known for years, but which were not previously recognized as interrelated. However, in accepting the ice dwarf hypothesis as a unifying solution to the low probabilities of the various observed characteristics of the Uranus, Neptune, and Pluto-Charon systems described above, it's natural to ask where all the ice dwarfs have gone.

The accretion epoch of giant planet formation ends when the growing planets either accrete all of the available material or gravitationally eject it from the formation region. Computer simulations of this process predict the ejection of comets from the Uranus-to-Neptune zone to the Oort cloud, which lies between a few thousand and fifty thousand AU from the Sun. Victor Safronov of the Sternberg Institute in Moscow and Julio Fernandez and Wing Ip (teaming together from their institutions in South America and Europe) have performed the most notable of these simulations.

Although the exact details of their results differ, both groups find that much more mass was ejected from the Uranus-to-Neptune zone than was incorporated into Uranus and Neptune themselves. This is because ejecting a body is dynamically more likely than capturing it. Furthermore, both groups found that much of this material was ejected from the solar system altogether. Only one-third of it or less was actually deposited in distant orbits in the Oort cloud.

Similar calculations also show that Pluto-sized planets are almost as easily ejected by Uranus and Neptune as comets are. This is because the ice dwarfs are 10,000 times lighter than Uranus and Neptune and therefore are relatively massless. This indicates that the ice dwarfs were nearly as easily removed from the Uranus-to-Neptune zone as the comets were, and that between 1 and 20 percent of the original population (several dozen to a thousand ice dwarfs) now reside in the Oort cloud.

Sleuthing the Herd

Since Clyde Tombaugh's discovery of Pluto in 1930, astronomers have searched repeatedly for a possible tenth planet. If the ice dwarf hypothesis is correct, not just one but perhaps tens or hundreds of planets remain to be discovered. However, because they are so small and distant, the ice dwarfs are beyond the 18th- to 23rd-magnitude limit of photographic surveys made to date. Typical visual magnitudes for an ice dwarf in the Oort cloud lie in the range of 31 to 37, depending upon the ice dwarf's size and distance.

Given such an observational challenge, how might astronomers

Icy Subdwarfs already discovered?

Phoebe

The search for ice dwarfs in the comet cloud is just beginning, but there is other evidence for this class of objects. Astronomers have already detected three small, icy bodies in the region between Saturn and Uranus. These icy "subdwarfs" are 2060 Chiron, Phoebe, and the newly discovered asteroid minor planet 5145 (1992 AD).

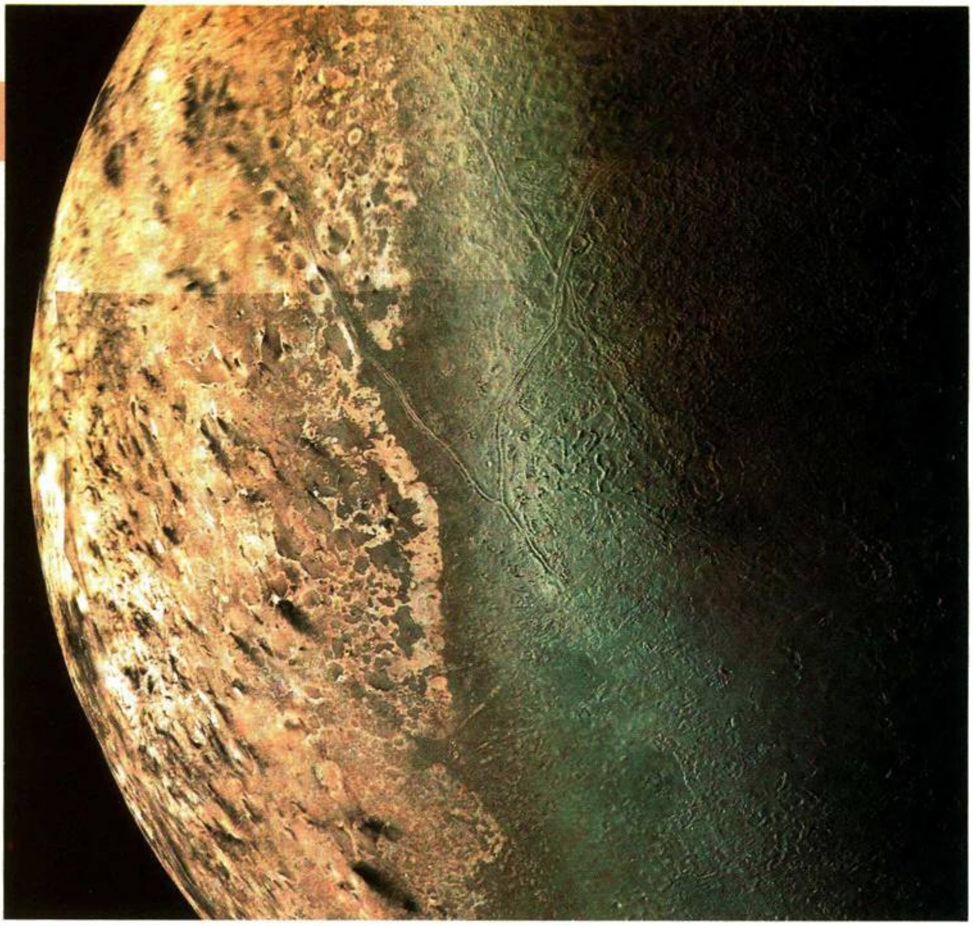
Astronomers usually classify Chiron, which was discovered in 1977, as the largest known comet. Chiron (not to be confused with Pluto's moon Charon) orbits the Sun in an unstable, 51-year-long orbit that ranges as close to the Sun as 8.5 AU and as far away as 19 AU. Estimates of its diameter range from 150 to 400 kilometers, making it about the size of the satellites Enceladus, Mimas, and Miranda. Chiron is 1,000 to 100,000 times as massive as a typical comet. In 1989, Chiron suddenly brightened and formed a coma, indicating its crust contains easily evaporated, or volatile, ices.

Computer modeling done by several groups indicates that Chiron most likely has not been in its present orbit for more than a few million years, which is a short time compared with the age of the solar system. Further calculations show that Chiron could not have stayed for a long time in an orbit close to the Sun or else it would have lost all of its ices. Hence astronomers believe Chiron is a recent and unusually large intruder from the Oort comet cloud.

Phoebe, a 160-km-wide satellite of Saturn, orbits on a retrograde path that indicates that it was captured from a heliocentric orbit. Whether this capture took place recently or soon after Saturn formed, roundish Phoebe may have formed directly in the solar nebula during the epoch of giant planet formation.

Like Chiron, the recently discovered minor planet 5145 is enormous compared with comets and asteroids of average size. Estimates give its diameter as 100 to 300 km. Its orbit is also unstable, taking 93 years to orbit the Sun, reaching in to 9 AU and straying out to 30 AU.

Apparently, at least three icy subdwarfs roam the outer solar system. Two of these bodies appear to have come from the outer reaches of the solar system because they lie in short-lived, unstable orbits. The presence of these icy subdwarfs in the outer solar system adds tantalizing evidence to the claim that many small planets orbit stealthily in the Oort cloud.



NEPTUNE CAPTURED TRITON early in the history of the solar system. But the capture almost certainly would not have occurred unless hundreds of Triton-like bodies roamed the outer solar system.

find these faint objects? Calculations show that a large infrared space observatory (such as SIRTF, the proposed Space Infrared Telescope Facility) could detect the faint thermal emission of ice dwarfs located as far away as 1,000 AU from the Sun. The European Infrared Space Observatory (ISO), planned for launch in 1993, could detect ice dwarfs inside 200 AU if a dedicated search were undertaken. Preliminary calculations show that up to 10 ice dwarfs might still orbit in this region. By comparison, searches for ice dwarfs by reflected light can reach out only 150 to 200 AU; they cannot hope to probe the Oort Cloud. And the chance that the motion of a still-working outbound Voyager or Pioneer spacecraft would be perturbed by an ice dwarf's gravity is negligible.

Even with a sensitive far-infrared observatory, locating remnant ice dwarfs will not be easy. Presumably, only a small fraction of the total population of ice dwarfs orbits inside 1,000 AU. These few bodies most likely are spread rather uniformly over the sky, making their detection difficult. But if we can locate several of these icy planets, we'll have confirming evidence that the solar system formed not only the nine planets of classical and telescopic discovery but also a great number of tiny worlds too.

Perhaps Not Nine, But Nine Hundred

Although astronomers have not yet detected any of these now-distant icy planets, there seem to be several lines of evidence indicating the presence of numerous ice dwarfs in the past. This strong but circumstantial evidence reminds us of archaeological studies that conclude early humans used fire at a given site, basing the conclusion on the presence of scattered flint tools and cooking utensils — even though there were no burnt logs themselves.

Still, direct detection of distant ice dwarfs will be required to seal the case. If distant ice dwarfs are discovered and their origin in the Uranus-to-Neptune zone is confirmed by detailed computer modeling, then our perspective on the outer solar system will undergo some significant changes:

First, Pluto will no longer be considered an oddity outside the paradigm of planetary formation. Indeed it, like Charon and Triton, would be viewed as one of the few remaining precious relics of the once-prevalent ice dwarf population. They will be immensely valuable for scientific study.

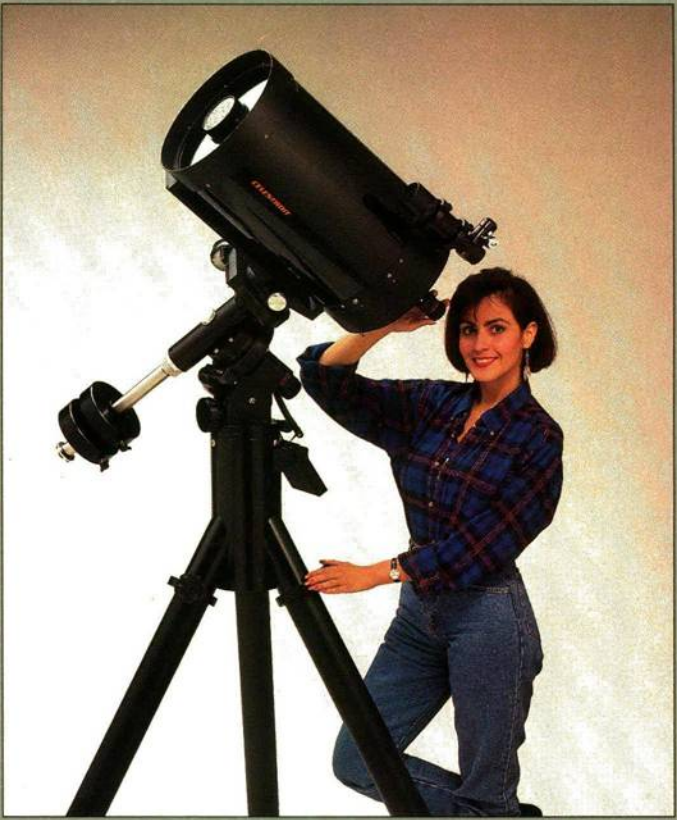
Second, we will see that the era of runaway planetesimal growth that led to the formation of Uranus and Neptune took place after (or lasted long enough to allow for) the formation of a significant number of giant planet embryos the size of planets and not just comets.

And last, our census of the solar system's planetary population will be dominated by a class of small, icy worlds not even recognized to exist until the great wave of spacecraft reconnaissance in the late 20th century was already complete. ☐

Alan Stern is a planetary scientist at Southwest Research Institute in San Antonio, Texas.

INTRODUCING A NEW CELE

THE CG-11 - A C11 REVOLUTION



Celestron Innovation... The new CG-11 combines the unequalled optical excellence of the current C11 with a superb new mount design.

The impressive mount is built for Celestron by Losmandy, a highly respected U.S. manufacturer. Five years of experience with this mount have brought about a mount with twice the rigidity at half the weight. The end product is SOLID with a dampening time so fast as to be almost unmeasurable. Legendary Losmandy tracking precision can now be yours in this affordable package.

The CG-11 package delivers an instrument that is easy to store, lightweight and portable. It will perform beyond your expectations providing both visual and photographic results guaranteed to impress even the most critical astronomer.

Standard features of the CG-11 (Model #11055) include:
C11 2800mm focal length (f/10) optics with Starbright® coatings, 30mm Ultima eyepiece - 1-1/4", 8x50 finderscope with LED illuminated reticle for straight-through or right angle viewing, quick-release finder bracket - no tools required; unique system - once it's aligned, each time it's removed and replaced, it will keep its alignment, prism star diagonal with multi-coatings - 1-1/4", visual back - 1-1/4", 2 adjustable counterweights - 11 lbs. each, 12V DC power, AC battery eliminator, 12 ft. cigarette lighter cord, Losmandy semi-pier tripod and hand control (see adjoining page), deluxe hard storage case for equatorial head, footlocker-style case for scope.

NUMEROUS OPTIONAL ACCESSORIES AVAILABLE. A fine complement of accessories for the CG-11 allows entry level through research level capabilities.

G-11 Mount (Model #93658) sold separately. Fits Schmidt-Cassegrains, Newtonians, Refractors and astrographs.

All the advantages of the new mount coupled with Celestron's own legendary C11 optics create an innovative new telescope. A scope that is user friendly - designed for the way you observe and photograph today. And with the versatility to expand to meet any of your needs in the future. For performance, precision, value and customer satisfaction, come see why Celestron has always been the leader.

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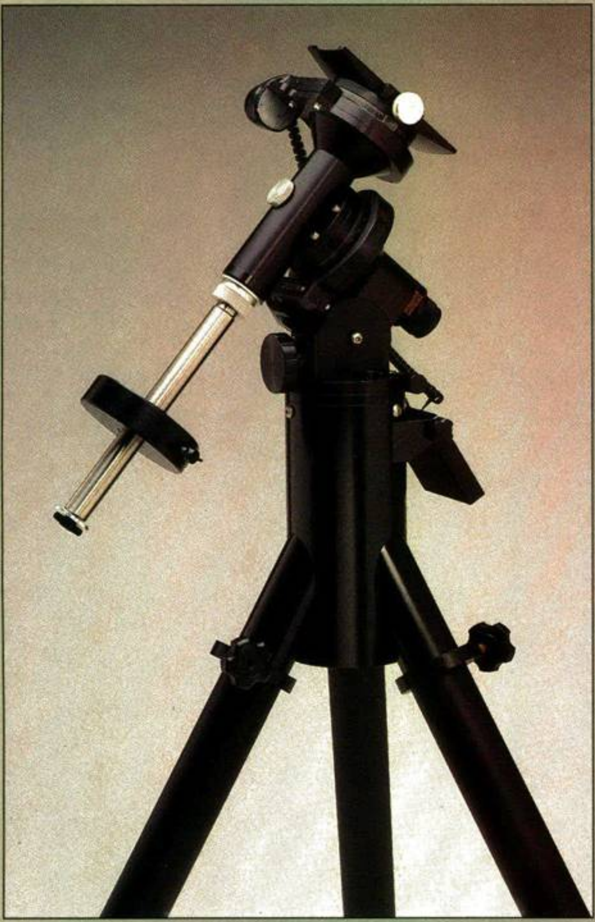
TRON MOUNT BY LOSMANDY



Celestron's new German equatorial mount, the G-11, is designed and built to set new standards in quality and performance. The all-machined equatorial mount is a work-of-art, displaying fully radiused edges, silk-smooth black anodized surfaces and stainless steel fasteners.

TECHNICAL FEATURES

Both axes are driven by a 5.6" diameter, 360 tooth worm gear. The high precision worms are hardened and precision ground stainless steel, double supported by preloaded ball bearings. 100oz./in. stepper motor drives provide reliable instantaneous response. The tracking accuracy is excellent.

The R.A. and DEC assemblies incorporate 5 ball bearings each. These axes are preloaded for zero play and variable friction clutched by a single knob. The 5" diameter laser engraved precision setting circles are readable to 1/4 degree in DEC and 1 minute in R.A.. The R.A. circle is direct reading indexed to the R.A. gear motion. All these technical features deliver the smoothness, refinement, controllability and precision that you've always desired in a fine mount.

TRIPOD

- Semi-pier tripod with 6" diameter center column.
- Removable 3" diameter legs with clamps and pod style feet.
- Standard leg length height of 48" for Schmidt-Cassegrains. Optional leg heights of 26" for Newtonians and 60" for refractors.
- All aluminum construction for maximum rigidity to weight ratio. Weight 20 lbs.
- Finished in an attractive semi-gloss black powder coat.

Above: Mount with Astro-Physics refractor

STANDARD FEATURES

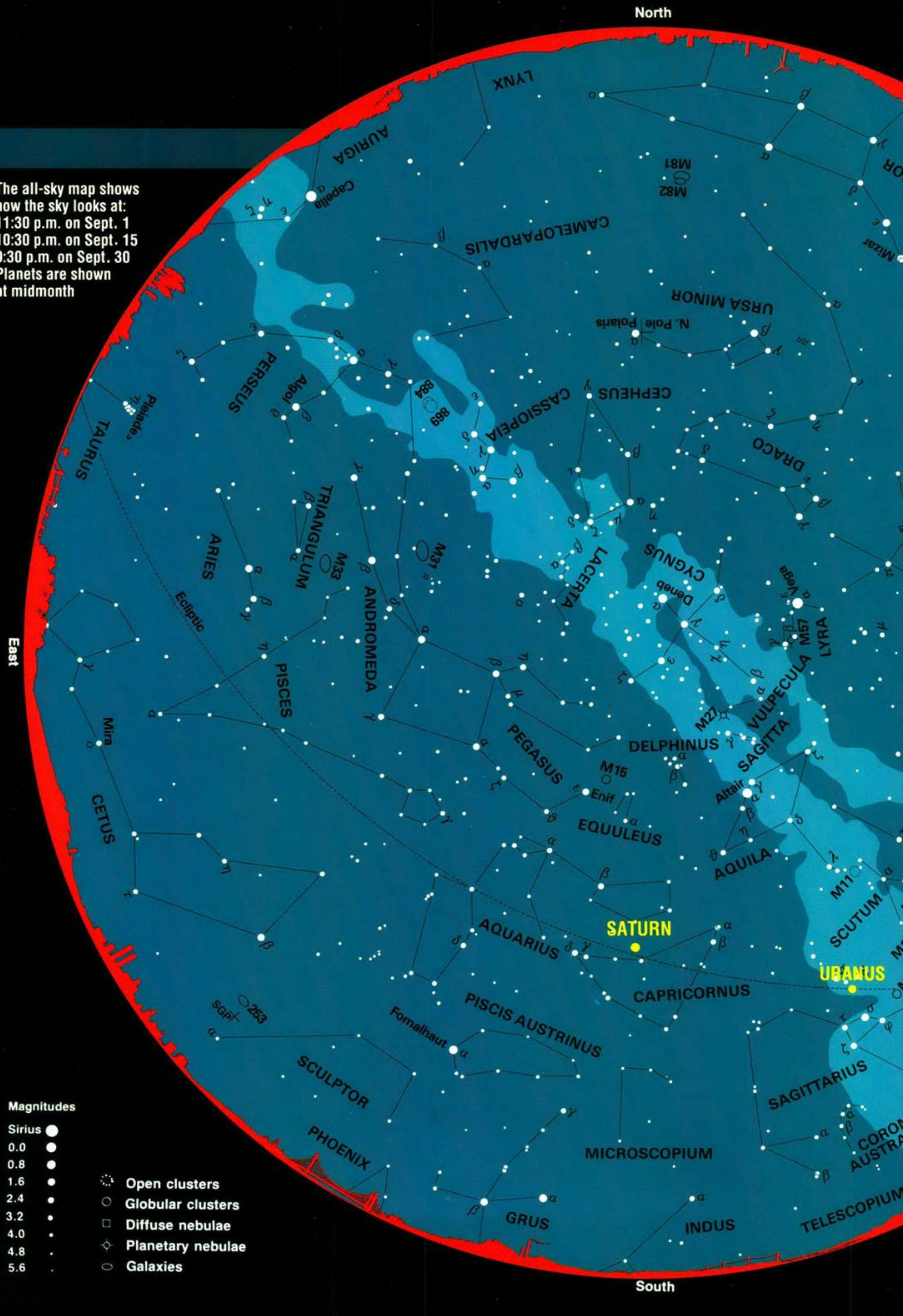
- Novel illuminated polar alignment scope has star patterns for both hemispheres and is very simple to use since indexing of longitude, date and time are no longer necessary.
- Stainless steel declination shaft is removable for compact transport.
- 2 DEC counterweights of 11 lbs. each.
- Fine elevation and azimuth polar adjustment of equatorial head.
- Removable declination saddle bar allows for rapid rebalance of DEC axis and the important versatility of interchanging various instruments from Newtonians to SCT's or refractors and astro cameras all with the same mount.
- Adjustable electronic control panel can be locked anywhere between horizontal and vertical reading positions providing optimal viewing angle.
- Weight of equatorial head is 31 lbs.
- Latitude range 12-64° (optional accessory 0-90°).
- Weight of equatorial head in deluxe padded carrying case 16-1/2" x 16-1/2" x 10" is 45 lbs.
- Nominal instrument capacity of the G-11 mount is 60 lbs.
- 17-1/4" long tube mounting dovetail bar.

DUAL AXIS ELECTRONIC CONTROL

- 3 photo guide rates of ± 30% and 50% for high quality guiding and 2x for coarse guiding or short focal length applications.
- 3 setting rates of 4x, 8x, 16x.
- Full feature PEC electronics.
- R.A. and DEC reversing switches allow for correct image motion/eyepiece view relationship. A "must have" for German equatorial mounts.
- Selectable quartz tracking rates - Sidereal, King, lunar and solar.
- Dimmable console displays and tiltable console viewing angle. Console location is also adjustable radially about column at 120° orientations.
- TVC - "Time Variable Constant" user programmable declination backlash compensation for instantaneous tracking response.
- Auto guider ready plus dual hemisphere operation.
- 12V DC cigarette lighter cord and AC battery eliminator included.

Check with your local Celestron dealer for a complete list of options for the G-11 mount.

The all-sky map shows how the sky looks at:
11:30 p.m. on Sept. 1
10:30 p.m. on Sept. 15
9:30 p.m. on Sept. 30
Planets are shown at midmonth


North
East
South
LYNX
AURIGA
Capella
M81
M82
CAMELOPARDALIS
URSA MINOR
N. Pole Polaris
Mizar
PERSEUS
Algol
Pleiades
TAURUS
884
869
CASSIOPEIA
CEPHEUS
DRACO
TRIANGULUM
M33
M31
ARIES
ANDROMEDA
LACERTA
CYGNUS
Deneb
Vega
M57
LYRA
Ecliptic
PISCES
VULPECULA
M27
SAGITTA
DELPHINUS
PEGASUS
M15
Enif
EQUULEUS
Altair
AQUILA
Mira
CETUS
M11
SCUTUM
SATURN
AQUARIUS
URANUS
CAPRICORNUS
SGP
253
PISCIS AUSTRINUS
Fomalhaut
SCULPTOR
SAGITTARIUS
CORON AUSTRA
PHOENIX
MICROSCOPIUM
GRUS
INDUS
TELESCOPIUM
Magnitudes
Sirius ●
0.0 ●
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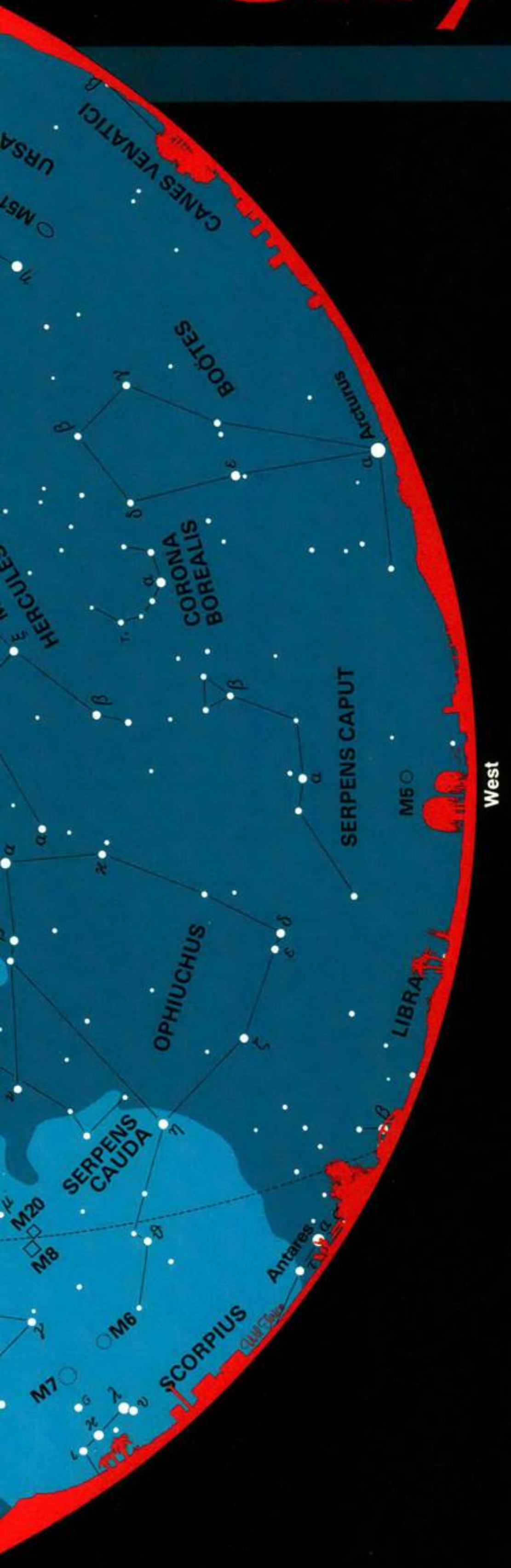
1.6 ●
2.4 ●
3.2 •
4.0 •
4.8 ·
5.6 ·
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

Sky Almanac

September 1992



SHINE ON, HARVEST MOON

On September 11 at dusk a large, yellow, bright Full Moon rises over the eastern horizon and fills the sky with moonglow. This Harvest Moon is traditionally associated with harvesting autumnal crops, but it also offers backyard astronomers the opportunity to observe lunar features at full illumination.

MERCURY AND REGULUS MEET

Shining at magnitude –1.2 and glowing with an orange hue, speedy Mercury whizzes past the bright star Regulus on September 2. Awake early, well before dawn, and you'll see in the brightening twilight the two objects separated by a mere 1.2°. Mercury lies north of the star, which is the brightest beacon in the constellation Leo.

MARS PASSES STAR CLUSTER M35

This month ruddy Mars has a close encounter with the star cluster M35. On September 15 the two objects are separated by less than 2°, affording binocular observers the chance to see the bright Red Planet together with a sparkling field of stars. Astrophotographers armed with telephoto lenses can capture the two objects with relatively short exposures.

Calendar of Events

2 Mercury passes 1.2° north of Regulus, 7 p.m. EDT
3 First Quarter Moon is at 6:39 p.m. EDT
6 The Moon passes 1.9° north of Uranus, 11:00 a.m. EDT
The Moon passes 0.9° north of Neptune, 3:00 p.m. EDT
9 The Moon is at apogee (253,799 miles from Earth), 3:00 p.m. EDT
11 Full "Harvest" Moon is at 10:17 p.m. EDT
15 Mercury is in superior conjunction, midnight EDT
16 Ceres is stationary
19 Venus passes 3° north of Spica, 1:00 a.m. EDT
Last Quarter Moon is at 3:53 p.m. EDT
20 The Moon passes 0.9° south of Mars, 5:00 a.m. EDT
22 Autumnal equinox is at 2:43 p.m. EDT
Uranus is stationary
24 The Moon is at perigee (224,955 miles from Earth), 11:00 p.m. EDT
26 New Moon is at 6:40 a.m. EDT
27 Neptune is stationary

Eye on the Sky

by Deborah Byrd

HARVEST MOONRISE

Autumn brings with it images of roundness, fullness, and completion. Traditional artists often personify this season — a time of harvest and fruit gathering — as a woman cradling an armload of ripe grapes. "Round" and "full" are also key words in this month's night sky. On the evenings prior to September 11, the bright golden ball of the Full Harvest Moon ascends over the eastern horizon not long before sundown. On September 12, the Moon rises within minutes of sunset for those in the northern United States and southern Canada. On both the 11th and the 12th, if you have a dark enough sky, you can look nearby for another full circle — this time made of stars — the faint Circlet asterism in the constellation Pisces.

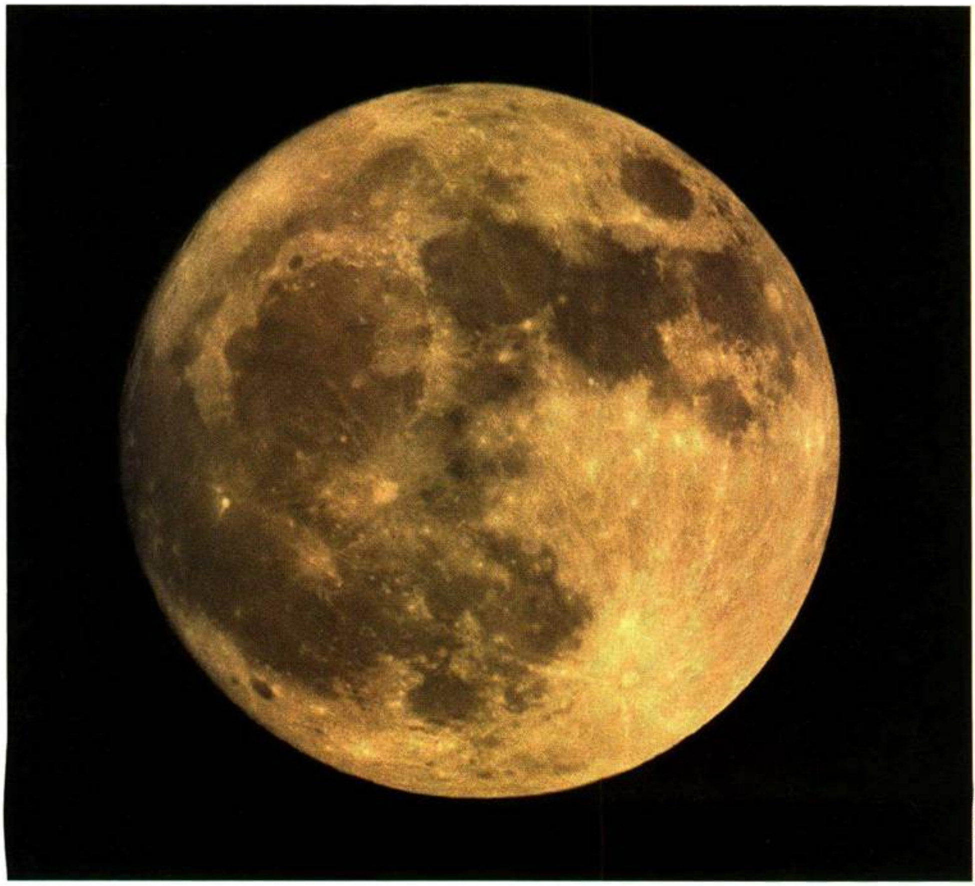
The Harvest Moon is the Full Moon nearest the autumnal equinox. It can occur in either September or early October. This year, the Moon reaches the crest of its full phase on the evening of September 11, and the equinox comes on September 22. According to folklore, the Harvest Moon appears bigger, brighter, and yellower than other Full Moons. The fact is that all Full Moons appear big and yellow as they're coming up over the horizon. The extra bigness of a Full Moon near the horizon is a perceptual effect known as the "Moon illusion." The yellow color of the rising Full Moon is a physical effect that stems from the scattering of light by the great thickness of air in the direction of your horizon.

So the Harvest Moon isn't bigger, brighter, or yellower than other Full Moons, but there's still something unique and wonderful about it. During the autumn months, the ecliptic — the path of the Sun, Moon, and planets — makes a narrow angle with the horizon in the evening. The Moon moves eastward along the ecliptic each day as it orbits around Earth. This movement causes the Moon to rise an average of about 50 minutes later each day. But at this season — thanks to the lazy angle of the ecliptic to the horizon — the time between successive moonrises is shorter. It's less than half an hour in some places. Thus, for several evenings in a row around this month's Full Moon, the Moon sails up over the eastern horizon just before or shortly after the time of sunset. It looks nearly Full on these nights. It's as though this month has several Full Moons instead of one! Each is a mirror of sorts to the ripe grain and fruit below.

Careful observers will notice something else. These harvest moonrises occur at a more northerly point along the horizon for some evenings in a row. The Moon's motion along the ecliptic this month translates to a motion northward along the horizon for each successive moonrise.

You might find yourself so entranced with this month's Full Moon that you decide to keep watching for the rest of the month. If so, you'll see the waning Moon sweep past the Pleiades star cluster on the morning of September 17. Then for a few days, the Moon is moving through the bright stars of the "winter circle" asterism. Last Quarter Moon comes on September 19. Then the Moon rises at mid-

THE HARVEST MOON appears big, yellow, and bright when it rises above the eastern horizon this September 11. How many dark markings are visible to the naked eye when the Harvest Moon rises?



Barbara Duffin

night and can be found in the south at dawn. Don't forget that when you gaze toward the Last Quarter Moon, you are looking in the direction of Earth's forward motion around the Sun.

AUTUMNAL EQUINOX

On September 22, at 2:43 p.m. EDT, the center of the Sun crosses the celestial equator, moving from north to south. This moment marks the autumnal equinox. It brings the first official day of autumn to the Northern Hemisphere and the first day of spring to those who live south of Earth's equator. On this day, the Sun has a celestial longitude of 180° and a declination of 0°. It shines as evenly on Earth's Northern and Southern hemispheres as it can. After this equinox, the Sun will continue taking a more southerly path across the dome of our sky each day. Its rays will heat our portion of Earth less effectively, and we'll all cast longer noontime shadows, until the Sun reaches its maximum southern declination of –23°27' at the December solstice.

SEPTEMBER'S PLANETS

Jupiter is visible in early September only to eagle-eyed observers or those with binoculars who have very clear western skies after sunset. It is very low in the western twilight at the start of the month. After the first few days, it's gone entirely, lost in the Sun's glare. Jupiter is in conjunction with the Sun, behind the Sun as seen from Earth, on September 17. It shows up again before the month ends, this time low in the east before dawn. A lesser planet wouldn't be visible so near the Sun, but Jupiter shines very brightly at magnitude –1.7. When it reappears, it has crossed a constellation boundary into Virgo.

Still extremely low in the west after sunset, **Venus** is nevertheless easier to see than Jupiter. It's higher in the sky than Jupiter and also brighter at magnitude –3.9. You can watch the bright star Spica sink toward Venus during the first half of this month. The two objects are closest around September 19, but by that time you'll probably need binoculars to see Spica so near the Sun's glare. Look for the Moon near Venus on the evening of September 28.

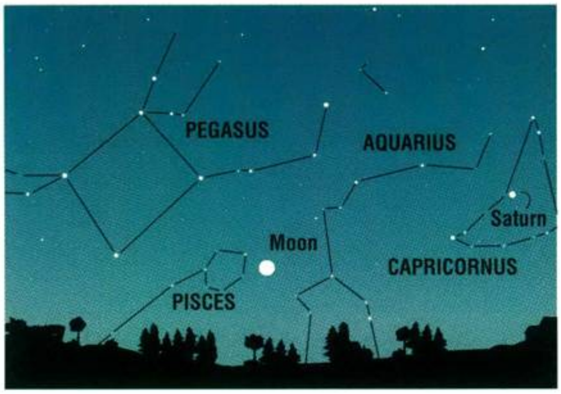
Saturn, in Capricornus, is low in the southeast at sunset. It can be seen for most of the night in September, a gentle golden light that doesn't twinkle, arcing across the sky. This planet is fainter now than it was a month ago. It shines at magnitude 0.4. Saturn is still moving in a retrograde, or westward, manner in front of the stars. It can be seen near the Moon on the night of September 8/9.

This month **Mars** continues rising in the middle of the night. It also continues growing brighter, increasing from magnitude 0.6 in early September to 0.3 in early October. Thus Mars outshines Saturn by the month's end. This planet begins the month in the constellation Taurus. It passes into Gemini in the course of the month, and in doing so it sweeps fairly near the somber red star Betelgeuse in the constellation Orion. You'll want to compare the colors and brightnesses of these two objects. Mars has grown brighter just as it has entered a region of the heavens populated by many bright stars, the stars of the "winter circle" asterism. Mars has a close conjunction with the Moon on the night of September 19/20, when the Moon occults Mars as seen from South America.

Mercury may be visible in the first few days of September, very low in the east-northeast before sunrise. Its superior conjunction, when it is behind the Sun from Earth, comes on September 14.

THE STARRY SKY

The small constellations scattered across the sky have been called "the mortar between the bricks" of the larger ones. Yet even the tiniest constellations have their own stories. They illustrate the fact that no region of the heavens lacks in wonders. This month and next, we'll consider four of the smallest of the 88 constellations: Vulpecula, Sagitta, Delphinus, and Equuleus. Three of these constellations are ancient; one is relatively new.



THE STARS OF PISCES, PEGASUS, AND CETUS surround the Harvest Moon when it rises on the evening of September 11.

They may be found on autumn evenings in or near the large asterism known as the Summer Triangle.

Although these constellations are little observed, they hold a fascinating array of unusual objects for binocular users. For example, Vulpecula the Fox contains one of the brightest planetary nebulae in the sky, the Dumbbell Nebula (M27). Glowing at 8th magnitude and measuring some 8' by 6', the Dumbbell is well beyond detection of the eye alone. However, a good pair of 7x50 binoculars reveals the Dumbbell as a tiny oval glow that appears fuzzy relative to the surrounding stars. The Dumbbell gets its inglorious nickname from its dumbbell shape, visible in small telescopes.

Vulpecula is the most recent of these four little patterns of stars. It was invented by Johannes Hevelius in 1690. The original name for this constellation was *Vulpecula et Anser*, or The Fox and The Goose. If you look, you'll see neither fox nor goose, but at best only a sprinkling of dim stars. I always have the impression that Vulpecula has a wide V-shape, but I wouldn't argue with anyone who disagreed.

The brightest star here, Alpha Vulpeculae, shines at magnitude 4.5. So you'll need a very dark sky, and preferably a moonless night, to see this constellation. Alpha Vulpeculae lies 3° almost due south of a famous double star in the constellation Cygnus, Beta Cygni, also known as Albireo.

Now, peering through your binoculars, extend the line from Albireo southward through Alpha Vulpeculae. You'll soon come to one of the most unfathomable (but cute) binocular objects in the sky. This is Brocchi's Cluster (Collinder 399), also known as The Coathanger for reasons that will become obvious as soon as it glides into your field of view.

Sagitta the Arrow is much easier to see than Vulpecula, despite the fact that it is the third smallest of all 88 constellations. Only Crux, known to us as the Southern Cross, and Equuleus the Little Horse are smaller.

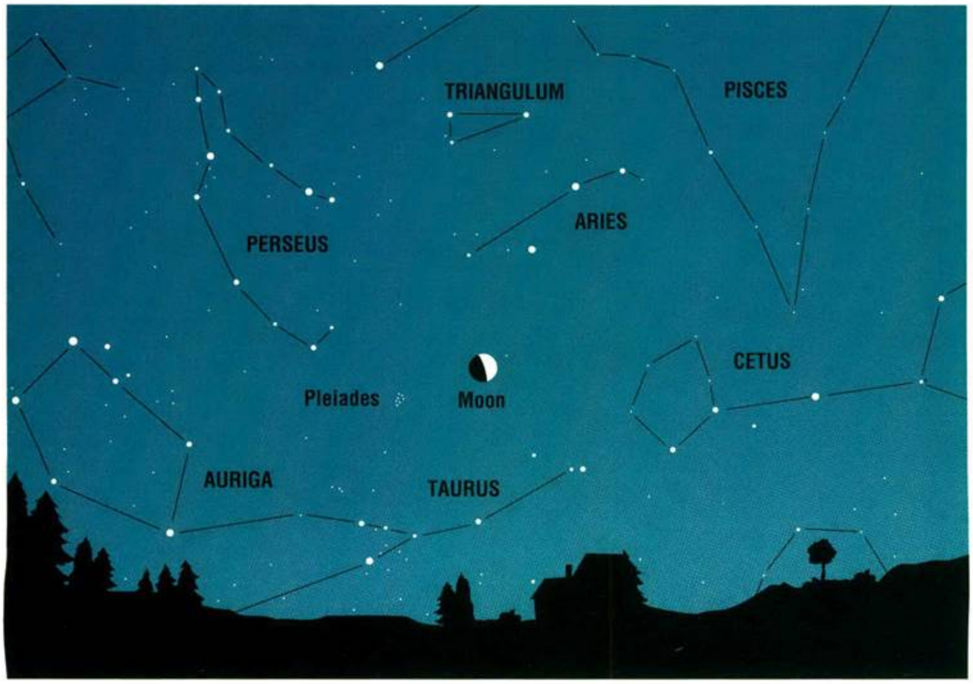
The stars of Sagitta aren't any brighter than the brightest star in Vulpecula. None of these stars is brighter than magnitude 4.4. Still, Sagitta is surprisingly easy to pick out because its stars really resemble an arrow. Gamma and Delta Sagittae form the shaft, and Alpha and Beta Sagittae are the feathers. Be sure to peer at this constellation through your binoculars. It's a pretty sight.

If you look closely through a pair of binoculars at the Sagitta region you'll see a fuzzy patch of light that appears to glow with the light of many individual stars. This is the globular star cluster M71 (NGC 6838), a spherical collection of several hundred thousand stars lying many light-years away in the halo of our Galaxy. Although it is not visible to the naked eye, M71 is a relatively easy object for binoculars on a moonless night.

This grouping of stars has been called an arrow in every known ancient reference. Sagitta is located north of Aquila the Eagle. On old star maps, it's occasionally depicted held in the Eagle's talons. It has been regarded as the arrow with which Apollo killed the Cyclops and as Cupid's Arrow. ☐

Deborah Byrd's radio series, "Earth and Sky," can be heard on stations throughout the United States, Canada, and Guam.

THE MOON MEETS THE PLEIADES on the evening of September 16. Spot the pair in the eastern sky amid the stars of Taurus, Perseus, and Cetus.



Through the Eyepiece *by Jeff Kanipe*

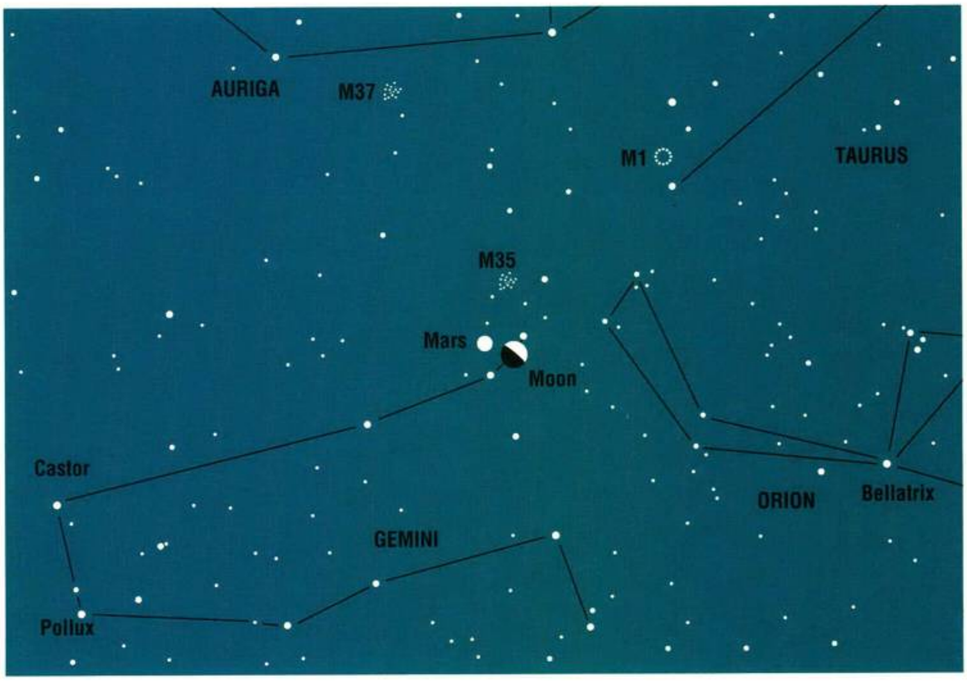
MARS RETURNS TO THE EVENING SKY

Only Saturn and Mars are high and well placed for observing in September and October. Of the two, Saturn is the more striking telescopic target, having just reached opposition last month. But Mars is a close second and over the next few months will be the planet to watch as it grows larger and brighter in the sky.

Mars has been a fairly inconspicuous object in the morning sky since January, when it was a magnitude 1.4 "star" in Aquarius. On September 10, though, Mars rises at midnight in Gemini and shines at magnitude 0.5. Twenty days later, Mars rises at mid-evening and its magnitude has increased by nearly two tenths.

Mars is the only planet that exhibits its surface to us in considerable detail. Unfortunately, the times when Mars appears favorable to us are fleeting. It comes to opposition once every two years, and exquisite detail is visible only for a few months on either side of that date. That period is beginning now. Its diameter of only 4,200 miles, coupled with its present distance from Earth of 118 million miles, translates into a modest-sized disk in the telescope. Mars' equatorial diameter is 7" at the beginning of September and slowly grows to 8" by the end of the month.

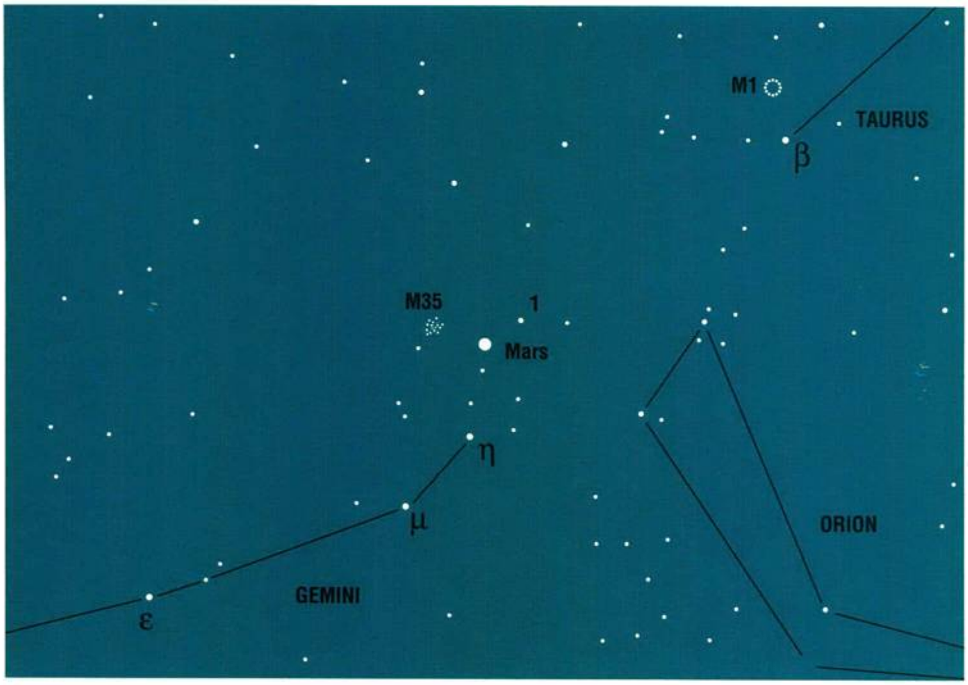
Although the disk is still too tiny for us to see much in the way of fine detail, it's a good time to begin studying Mars and training the eye to see at least the conspicuous surface features visible in a small telescope. By small I mean at least a 3-inch refractor with a minimum magnification of 120x or a 6-inch reflector at 250x. Such a combination of instrument and magnification should enable you to detect the bright white north polar cap (presently tipped toward Earth) as well as the dark, wedge-shaped Syrtis Major and elongated Sinus Meridiani, both of which cross the equatorial region of the disk. In the planet's southern hemisphere, you should have no trouble spotting Hellas, a circular desert plain that can sometimes be as bright as the polar caps. Hellas lies south of Syrtis Major, which, in a telescope that inverts images, will be above that feature.



MARS, THE MOON, AND M35, a star cluster in the western part of Gemini, form a tight group on September 20, when separated by only a few degrees.

Though you will probably at first perceive only an ochre-hued blob, don't get discouraged; continue observing. Perception is a tricky thing, and after a while, the features that you suspected were there all along will solidify into reality for brief moments as the seeing comes and goes. Keep practicing. Train your eye to remain relaxed and to extract as much detail as possible from the elusive markings on the disk during moments of good seeing.

With patience, you may find that your small telescope reveals surprisingly fine features, even though they are theoretically below your resolving limit. The reason is that Martian surface features have a rather high contrast when Earth's atmosphere is steady and the Martian disk is bright. Hence, light-gathering power here is not as important as good seeing and fine-tuned, well-collimated optics. Larger apertures may be able to detect lower-contrast features, but consider that the Dawes' limit of the telescope applies only to the separation of point sources, not the resolution of linear features such as those that make up the surface markings of Mars.



A CLOSE ENCOUNTER of the best kind occurs on September 15 when Mars sneaks past the cluster M35. On this night, the two objects are visible in the same low-power eyepiece field.

Of course, you may think you're pushing your telescope and eye to their limits, but in reality, you are doing the typical work of a planetary observer. The sweat that trickles from your brow, the tightness in your chest from holding your breath for extended periods, and the strain you feel in your neck from keeping still at the eyepiece are the standard byproducts of serious observing. After all, you can't expect your telescope to do *all* the work, can you?

After you gain some experience observing the disk of Mars, you'll come to recognize some of the Red Planet's most distinctive features. Prominent dark areas along the equatorial region of the planet include Mare Sirenum, Solis Lacus, Mare Erythraeum, Sabaeus Sinus, Meridiani Sinus, Mare Tyrrhenum, and Hesperia. Less contrasty dark features are visible in the southern and northern hemispheres of the planet. These include Mare Australe, Mare Chronium, Mare Oceanidum, and Mare Amphitrites in the southern hemisphere, and Mare Acidalium, Cebrenia, Umbra, Cydonia, and Aetheria in the northern hemisphere. Additionally, bright features are occasionally visible as they stand out from the dusky surface of the planet. These include Hellas, Arabia, Elysium, Tharsis, Memnonia, Amazonis, and Arcadia.

The bright and dark features on the Martian surface are simply areas of high or low albedo, or reflectivity. They do not necessarily correspond to specific geographic features. The surface features vary from season to season and from year to year. Astronomers do not yet know whether the patterns change systematically or randomly. Most of the seasonal changes occur as dust storms sweep across the surface of Mars and redistribute the pattern of dark and light areas in a matter of hours. During some of the most severe dust storms of recent years, virtually all of the markings on the planet have disappeared except for the polar caps.

When you observe Mars and its surface markings, you might find it helpful to employ colored filters that screw into your eyepiece. For example, a blue (Wratten 38A) filter shows hazes and high-altitude clouds that lie above the planet's surface and are most easily visible along the limbs. A blue-green (Wratten 64) filter serves nearly as well for this cloud hunting. Dust storms and yellow clouds stand out prominently when viewed with a Wratten 8, 12, or 15 yellow filter. Orographic clouds that form during the Martian daytime are best viewed with a violet or blue filter.

The next time you go out to observe Mars, take a few sheets of paper, a soft pencil, and a dim red flashlight. After you carefully gaze at the planet for some time, try making a sketch of what you see. The number of details clearly visible will surprise you, and if you continue sketching Mars at regular intervals, the detail you record will continue to grow.

SATURN'S SHADOW SHOW

Speaking of perception effects, take a look at Saturn this month. No other planet looks as three-dimensional in the eyepiece as the ringed wonder. The razor-sharp ring plane encircling the globe makes the planet appear like a tiny, well-defined model hanging in front of a black backdrop. This 3-D view often has a dramatic effect on first-time Saturn viewers. They gasp, clutch themselves, and even rear back suddenly from the eyepiece as if they've just had ice dropped down their pants (the notorious Saturn effect). Sometimes they look askance and ask in an undertone if they're perhaps looking at a photo of the planet. I tell them that if Saturn looks unreal it's because it looks too real. It practically pokes out of the eyepiece.

Now that Saturn is a month past opposition, you can see the shadow cast by the ball onto the rings, and this gives it an even more eye-popping effect. You'll begin to see this effect toward the end of the month. Before opposition, the shadow from the ball is cast toward the preceding side of the rings, the leading side of the planet moving toward the western horizon. After opposition, as it is now, the shadow falls on the following side. In a telescope that inverts images, the shadow appears on the left side (ball up, rings down). This soon after opposition, the shadow looks like a black, narrow slice just off the limb where the rings go around the backside of the planet.

As the months progress, the shadow from the ball will become more obvious as it broadens across the rings. By the end of the year, it will look like a wedge-shaped void in the ring plane. The inclination of the rings, though decreasing, is still large enough to see this phenomenon. Right now, the rings are tilted a little over 17° toward Earth. This diminishes to 16° by the end of the year, not enough to hide the shadow.

If you find this kind of shadow play illuminating, try looking for the shadow cast on the disk itself by the rings passing in front of Saturn. Given Saturn's current orientation and ring tilt, the shadow is cast on the equatorial region and looks very much like a narrow dark belt crossing the planet just above the ring plane.

ASTEROIDS IN THE EYEPIECE

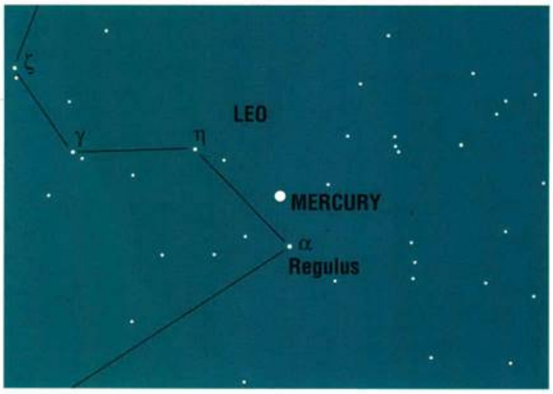
It's pretty quiet on the minor planet front this month, though one or two possibilities exist.

The asteroid 1 Ceres is currently traversing the southeasternmost reaches of Sagittarius. At magnitude 8.4, it is still a noticeably bright object, though it gets lots of competition from the rich star fields of the area. Ceres is just coming out of its retrograde loop and will soon be heading east again with respect to the background stars. This month it transcribes a tiny arc in the sky 4.5° due east of the fine globular cluster M55 in Sagittarius (which is itself about the same angular distance southeast of the constellation's teapot handle). During the entire month Ceres remains confined to an area of sky no larger than a half degree. If you have an equatorial mount you can easily pinpoint Ceres' field by placing M55 in the center of the field of view and then moving the telescope eastward in right ascension by roughly 30 minutes — don't change declination. Carefully sketch all the positions of the stars, being sure to note your sky directions. Come back the next night (or the next if it's cloudy) and look at the field again. Compare the positions of the stars with those on your chart. Only one "star" should have moved, and that's Ceres. If they all moved, or if none of them moved, you'll have to draw the chart again.

While you're in the area, try for 68 Leto, now moving westward in Aquarius. Look about 20° northeast of Fomalhaut in Piscis Austrinus, or $2^1/_2$° northwest of 98 and 99 Aquarii. Leto remains at magnitude 9.7 all month, and its motion should be easy to distinguish against the sparsely populated backdrop of stars over a period of a few nights. As with Ceres, compare its position with those of the background stars and see which dot moves.

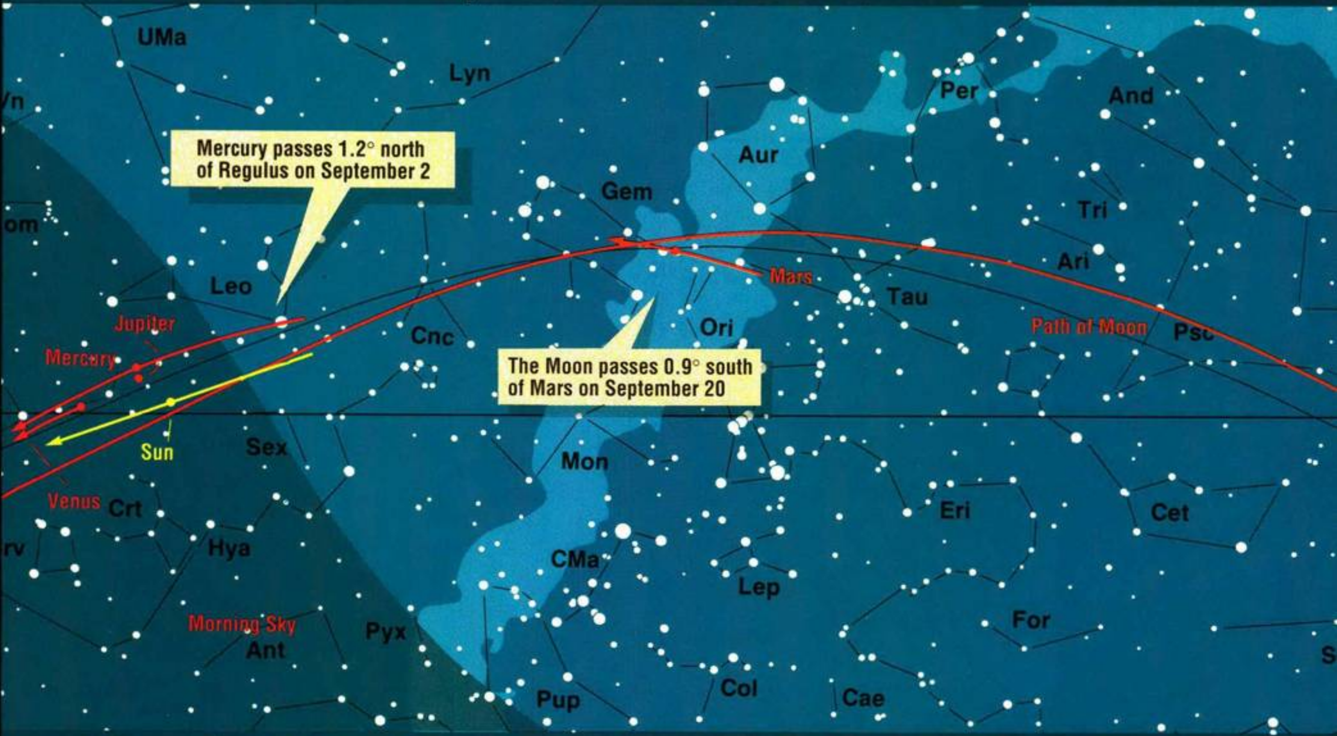
Finally, 3 Juno lies in the after-midnight sky. If you're so inclined, you can find it $3^1/_2$° northeast of Betelgeuse late in the month. It shines at 9th magnitude during September but continues to brighten through December. Juno reaches perihelion on September 17. On September 24, it slips a half degree south of 3rd-magnitude Mu Orionis. This might be a good opportunity to begin photographically documenting its path through Orion and into Monoceros, where it does its retrograde loop in November and December. Use a telephoto lens and fast film. □

Jeff Kanipe is the editor of StarDate *magazine, which is published by McDonald Observatory at the University of Texas at Austin.*



EARLY IN THE MORNING on September 2 you can spot Mercury and Regulus as they form a dazzling pair in the dawn sky.

The Solar System September 1992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Sun
Sex
Mon
Venus
Crt
Eri
Cet
Hya
CMa
Lep
Morning Sky
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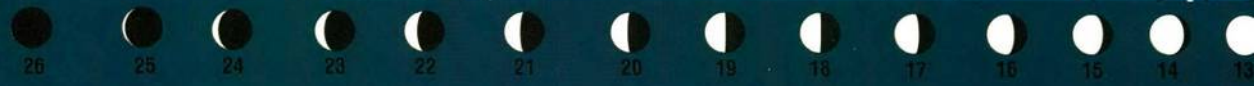
Mercury passes 1.2° north of Regulus on September 2

The Moon passes 0.9° south of Mars on September 20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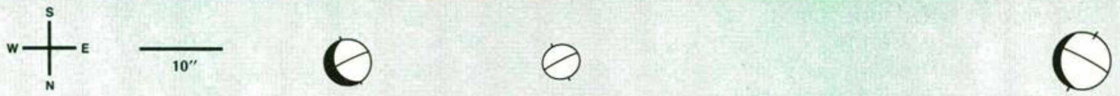
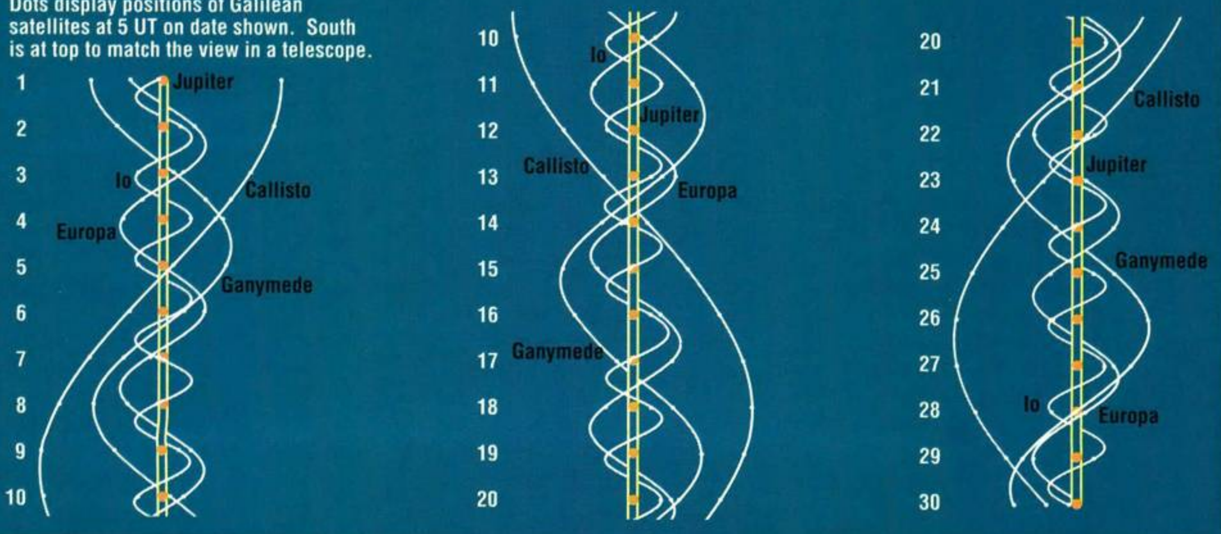
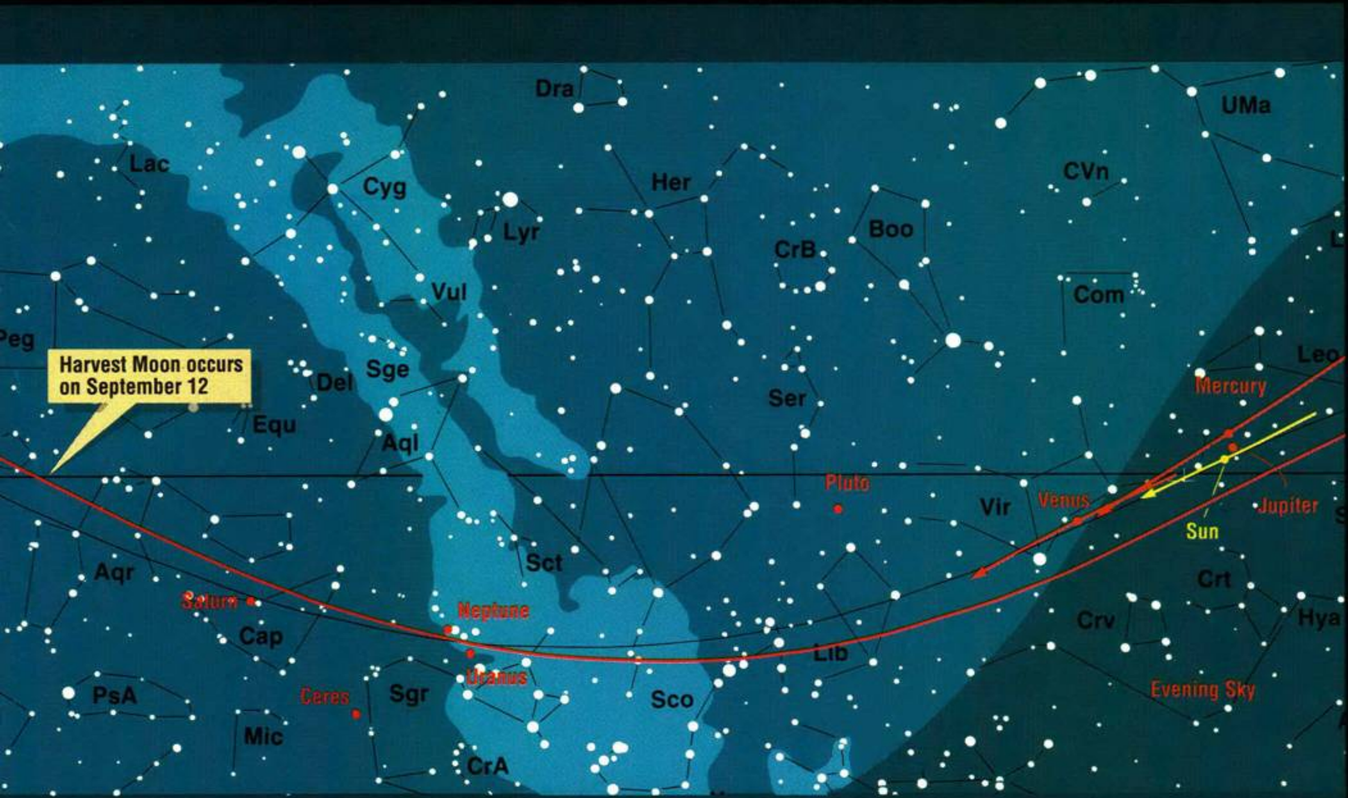


Planet	MERCURY	MERCURY	VENUS	MARS
Date	September 1	September 15	September 15	September 15
Magnitude	–1.2	–1.7	–3.9	0.5
Angular Size	5.7"	4.9"	11.1"	7.5
Illumination	84%	100%	90%	87%
Distance (AU) from Earth	1.191	1.380	1.494	1.245
Distance (AU) from Sun	0.311	0.377	0.723	1.471
Right Ascension (2000.0)	9h54.0m	11h34.5m	13h06.2m	6h07.2m
Declination (2000.0)	+14°15'	+4°29'	–6°21'	+23°25'

Jupiter's Moons

Dots display positions of Galilean satellites at 5 UT on date shown. South is at top to match the view in a telescope.

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CrB
Vul
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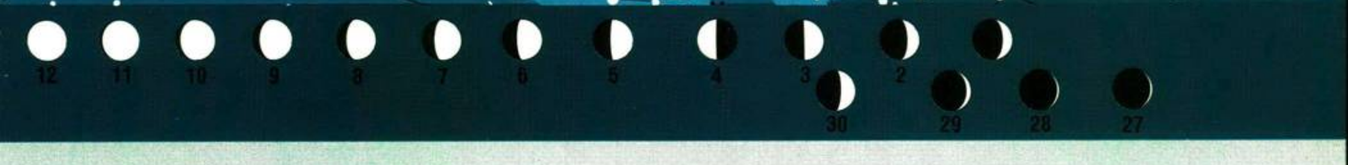
Pluto
Vir
Venus
Jupiter
Sun
Sct
Aqr
Crt
Saturn
Neptune
Cap
Crv
Hya
Lib
Uranus
PsA
Ceres
Sgr
Sco
Evening Sky
Mic
CrA

Harvest Moon occurs on September 12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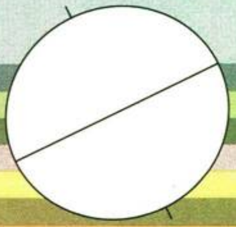
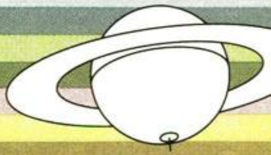
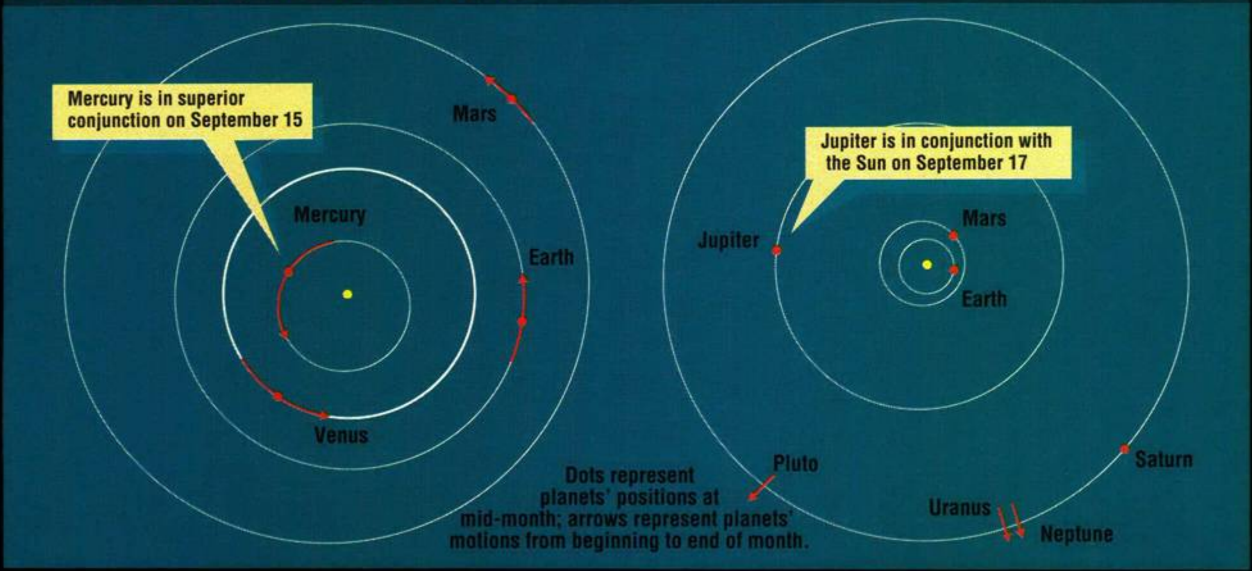




JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
September 15	September 15	September 15	September 15	September 15
−1.7	0.4	5.7	7.9	13.8
30.5"	18.2"	3.7"	2.3"	0.1"
100%	100%	100%	100%	100%
6.441	9.094	19.160	29.769	30.208
5.437	9.887	19.553	30.190	29.709
11h41.9m	21h01.9m	19h01.8m	19h10.5m	15h28.7m
+3°07'	−18°01'	−23°07'	−21°44'	−4°26'

The Planets in Their Orbits

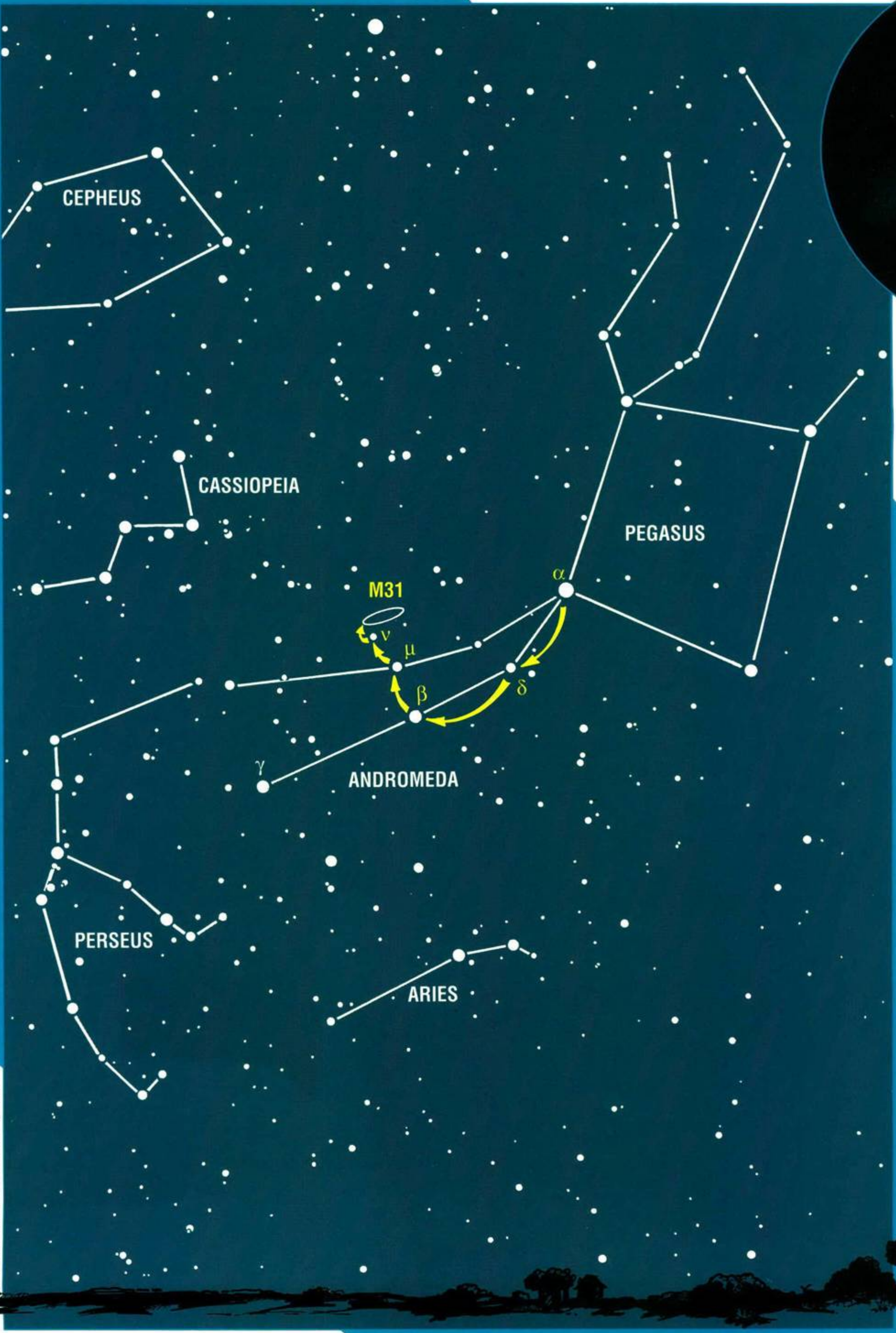

Mars
Mercury
Earth
Venus
Jupiter
Mars
Earth
Pluto
Saturn
Uranus
Neptune

Mercury is in superior conjunction on September 15

Jupiter is in conjunction with the Sun on September 17

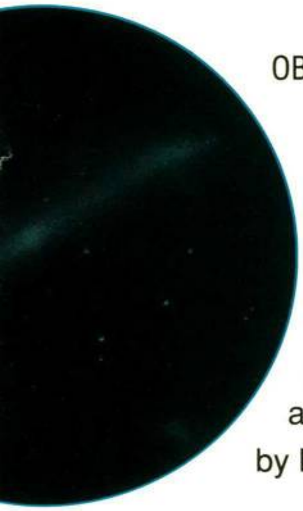
Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

Jeffrey Corder


CEPHEUS
CASSIOPEIA
PEGASUS
M31
α
ν
μ
β
δ
γ
ANDROMEDA
PERSEUS
ARIES

ASTRONOMY: All star maps by Lee Vande Visse

OBSERVING TECHNIQUES



HOP INTO DEEP-SKY OBSERVING

Hopping from star to star can be the easiest and most rewarding way to locate deep-sky objects.

by Marcel W. Bergman

The Moon is New, the night sky steady and transparent. Starlight glints on the shiny tube of your new telescope. Multiple stars, star clusters, nebulae, and galaxies await you on this, your maiden voyage into deep-sky observing. How you prepare for this initial expedition can make all the difference in the world. You can enjoy hours at the eyepiece losing yourself to the splendors of deep space, or pore over star charts and peer through your finderscope only to find yourself deeply lost in space. You can finish the night with warm memories of your observations, or pack up early feeling cold and frustrated. Your first steps into deep-sky observing can profoundly affect the longevity of your new hobby. Too often, tripping unprepared over the threshold of deep-sky observing culminates in the epitaph: "Telescope for sale. Rarely used."

For a successful observing session, you need to devise a strategy for finding your way. For a novice observer, locating faint celestial treasures in the inky voids that lie amid the chaotic array of stars is an imposing task. It certainly proved one to me. Before I bought my first telescope, I searched for advice on navigating the sky. I learned all I could about the two basic methods: setting circles and star hopping. In my experience, star hopping is the clear winner.

Moving Around in Circles

Setting circles are the dials you find on the two axes of an equatorial mount. The right ascension setting circle is the dial around the polar axis. The other setting circle surrounds the declination axis. To find a celestial object using setting circles, you first need to look up its right ascension and declination coordinates in an atlas, then dial in these coordinates on the setting circles, and *voila!* — the telescope should be pointing at the object. Unfortunately, in my experience, the scope is just as likely pointing at the ground.

There were other reasons that made me choose to star hop to deep-sky objects. Terrestrial navigation is ultimately based on the stars; surely the stars are the most obvious beacons for journeys in space. My reading confirmed this logic, revealing phrases like, "M27, the Dumbbell Nebula, lies 3.3° due north of the star Gamma Sagittae." I never read instructions such as, "Find M27 at right ascension 19 hours 59.6 minutes and declination +22°43'." But what really made me choose star hopping was the advice of many veteran observers. They told me star hopping was the only way to really learn the sky. It made sense to me. I was bound to see and learn more on a trip that starts somewhere other than my destination.

Unfortunately, I never got specific advice on how to star hop. I figured it was easy. Just aim the scope along patterns of stars that progressively zero in on the target. It was a simple follow-the-dots. What more did I need to know?

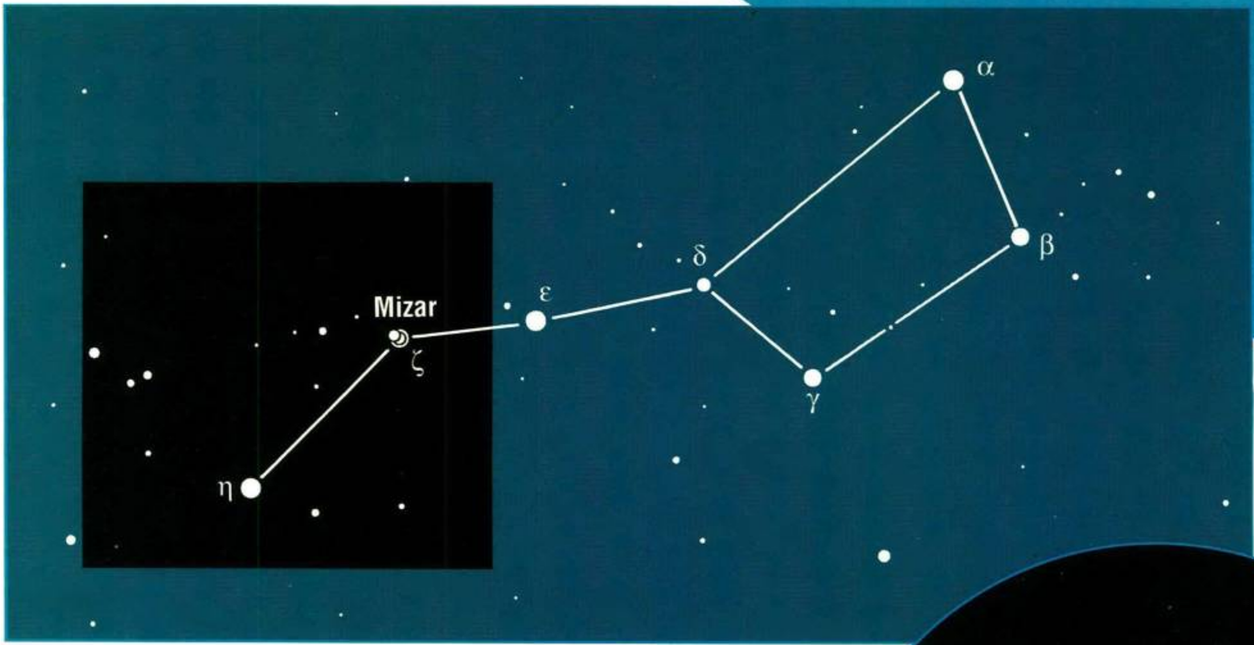
Not So Fast

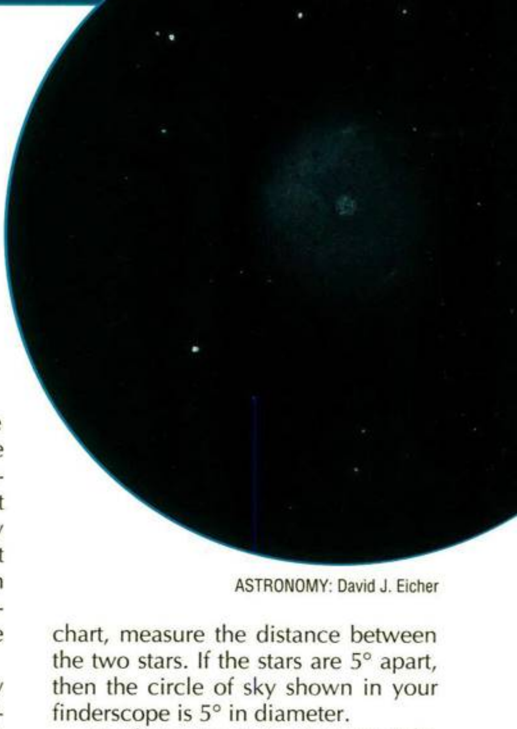
The first night with my brand new telescope dealt my star hopping career a major blow. For the first several minutes, I kept switching my attention between the finderscope view and the star chart, trying to lock onto a pattern in the myriad stars that filled the field of the finder. The inverted image I saw in the finderscope conflicted with my memory of the star pattern I had seen on the chart. Eventually, I forgot what it was I had set out to find.

I returned to my star atlas, red penlight in hand, to choose an easier object to find. Then, pasting my eye to the finderscope, I weaved the telescope this way and that, while the

Vande Visse

ONE OF THE EASIEST STAR HOPS is to M31, the Andromeda Galaxy. M31 lies 2° northwest of Nu (ν) Andromedae, which itself is a simple four-step hop from 2nd-magnitude Alpha (α) Andromedae.





THE BIG DIPPER SERVES as your starting point (above) for finding the spiral galaxy M101. From the double star Alcor and Mizar, hop east along a string of five stars until you reach the deep-sky landmark (right).

ASTRONOMY: David J. Eicher

view in the finder wound that way and this. After several more minutes all I had to show for my efforts was a stiff neck and cold feet. I stumbled back to the star charts, my enthusiasm fading like the batteries in the red penlight that inadvertently had been illuminating the inside of my jacket pocket. I realized that celestial follow-the-dots was more complicated than the pencil-and-paper variety I grew up with.

Fortunately, star hopping improves with practice. I finally started finding some bright nebulae and star clusters. But whenever I looked for a faint galaxy or nebula, my hop slowed to a crawl. I decided to re-evaluate my whole star-hopping technique. Instead of plunging headlong into deep space as I had been, I now would hop methodically. I planned my next deep-sky observing session as though it would be my first.

Getting It Right

I found that to star hop efficiently, you need to familiarize yourself thoroughly with the set-up and operation of your telescope. If it's a new telescope, practice using it in daylight. Practice slewing the telescope on its axes. Practice using the slow-motion controls. The first time you use your telescope under the night sky, practice finding easy subjects like the Moon and planets using the same techniques you practiced in daylight.

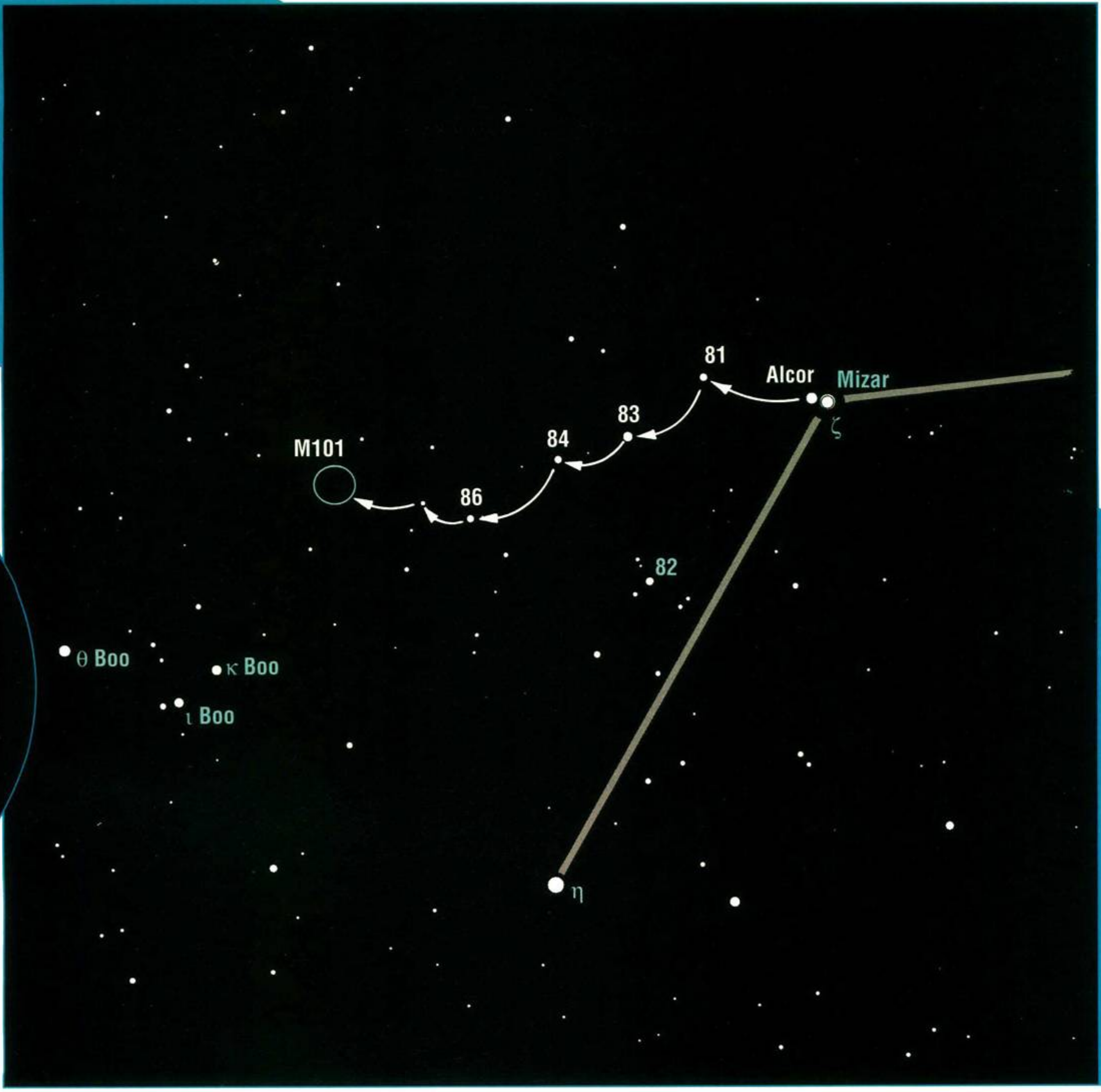
As you build confidence in operating your telescope, also learn about your finderscope. If it has a right angle prism, it will produce an image that is right side up but reversed left to right. If it is a straight finderscope, the image will be both upside down and reversed left to right. Look through the finderscope while you move the telescope with the slow-motion controls. When you move the scope east or west, the view in the finderscope pans in the opposite sense. The same is true for movements north and south with a straight finderscope. Get these potentially disorienting effects straightened out in your mind. If you concentrate on the physical movement of the telescope, the view in the finderscope won't fool you.

The finderscope is your primary aid in star hopping. Collimate it accurately — in other words, make sure it points in precisely the same direction as the main telescope. It's easiest to collimate the finderscope in daylight. Point the telescope at a distant terrestrial object — a mountain, tall building, or other landmark a mile or more away works best — and center the object in the telescopic field of a low-power eyepiece. Then without moving the main telescope, adjust the finderscope so that the object is centered in the finder's field.

You'll also want to determine the size of your finderscope's field of view. Some finders have the field of view marked on their sides. If yours does not, take the scope out on a clear night and aim it at a pair of stars that just fit in the field. Then on a star chart, measure the distance between the two stars. If the stars are 5° apart, then the circle of sky shown in your finderscope is 5° in diameter.

An alternative is to aim your telescope at a star near the celestial equator (a star with a declination close to 0°) and center the star in the finder's field. If you are using a clock drive, turn it off. Measure the time in minutes it takes for the star to drift out of the field and divide this time by two. The result is the angular diameter in degrees of the circle of sky that you see in your finderscope. For example, if it takes ten minutes for the star to drift from the center to the edge of the field, then your finderscope shows a patch of sky 5° across. Now when you want to move the telescope 5°, you know you need to pan through one field in the finderscope.

Once you've figured out the finderscope's field, you should make a



circular overlay of the same size for your star atlas. Simply determine the angular diameter of the finder's field at your atlas' scale and cut a circle of that size out of a piece of paper. You can then use the cutout to quickly compare what you see in the finder with the stars shown in your atlas.

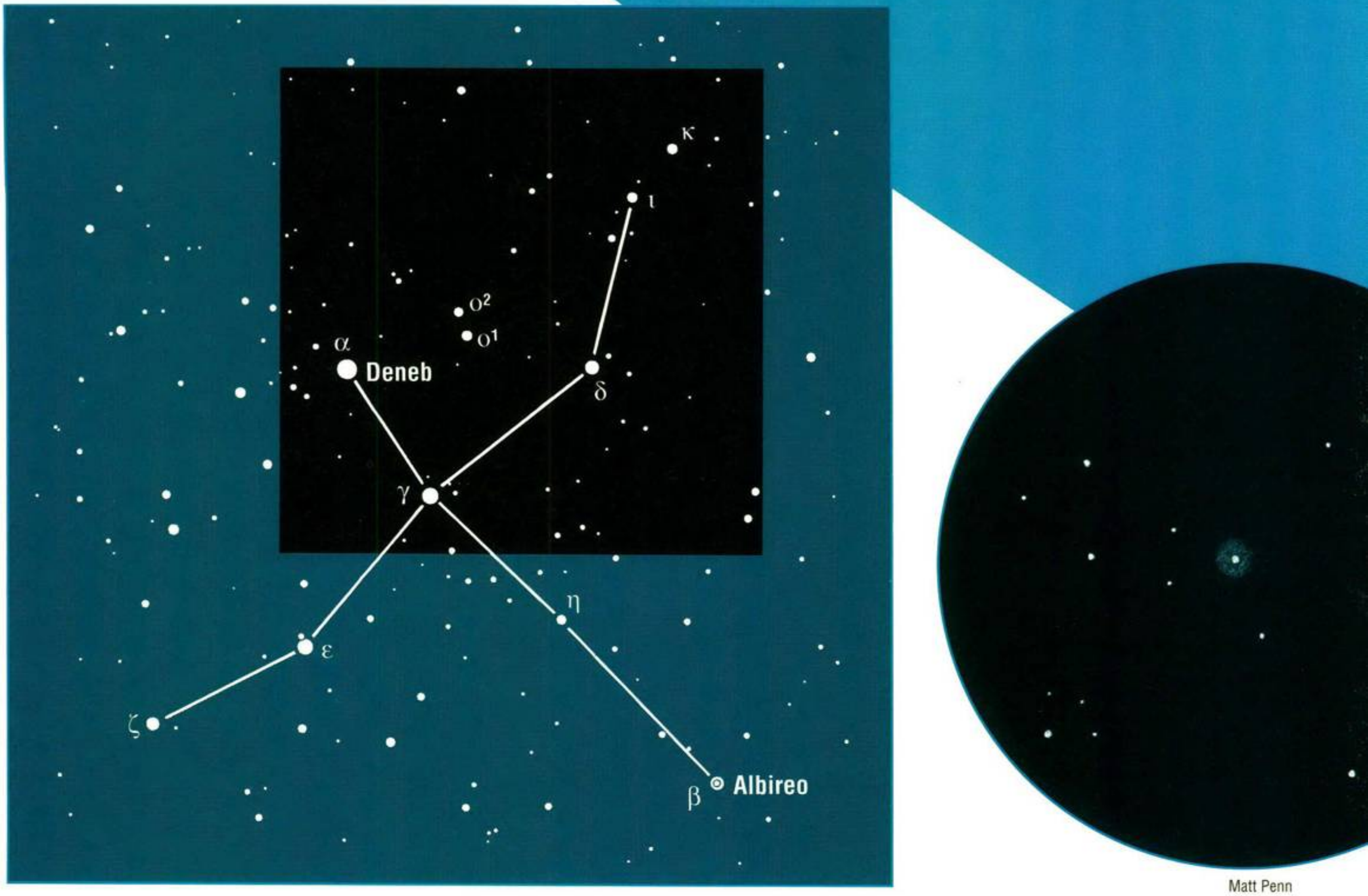
Hop to It

Now you're ready for your first foray into star hopping. Luckily the autumn evening sky offers a nearly perfect deep-sky object for getting started — the Andromeda Galaxy, or M31. Not only is M31 bright enough to see with the naked eye from a dark-sky site (and from virtually anywhere with binoculars), but also all of the stars leading to it are visible without optical aid. You can star hop with confidence because if you lose your way, you can get back on track simply by glancing at the sky.

To find M31, pick a nice clear autumn evening when the Moon is either a slim crescent or out of the sky altogether. (In September, that means the first few days of the month or any time after mid-month.) After you arrive at your observing site, set up your telescope. While your eyes adapt to the darkness and your telescope adjusts to the ambient air temperature, locate the star at the beginning of your intended hop.

For the hop to M31, this is easy. Around 9 p.m. in mid-September, you can find the Great Square of Pegasus about halfway up in the eastern sky (see the map on page 60). Your starting point is the 2nd-magnitude star Alpheratz, also known as Alpha (α) Andromedae, which marks the northeast corner of the Great Square. Now center Alpheratz in your finderscope and confirm that its image is also in the center of the main telescope's field.

Your first hop takes you 7° east-northeast from Alpheratz to 3rd-



Matt Penn

THE BLINKING PLANETARY (NGC 6826) lies in northeastern Cygnus (left), just a short hop from Gamma (γ) Cygni, the center of the Northern Cross (right).

magnitude Delta (δ) Andromedae. Use the slow-motion controls to slew your telescope to this star, then sight along the scope's barrel to be sure you're pointing at the right star. Once you've found Delta, hop another 8° northeast to the 2nd-magnitude star Beta (β) Andromedae.

Next, hop 4° northwest from Beta to 4th-magnitude Mu (μ) Andromedae, then 3° north-northwest to 5th-magnitude Nu (ν) Andromedae. M31 is a short hop, just 1.5°, west of Nu.

Though star hopping to M31 is about as easy as it gets, it illustrates the techniques you'll need for other, more difficult star hops. First, make up a detailed plan for hopping to each of the deep-sky objects you want to observe. What you're looking for are recognizable star patterns that will lead you from a naked-eye star (preferably one 4th magnitude or brighter) to the deep-sky object. When you're out at your site waiting to get dark-adapted, reconnoiter the constellations you plan to explore and identify the naked-eye stars that will serve as your hopping-off points. When you are ready to hunt for a deep-sky object, center the lead star and then use the slow-motion controls to star hop to your goal.

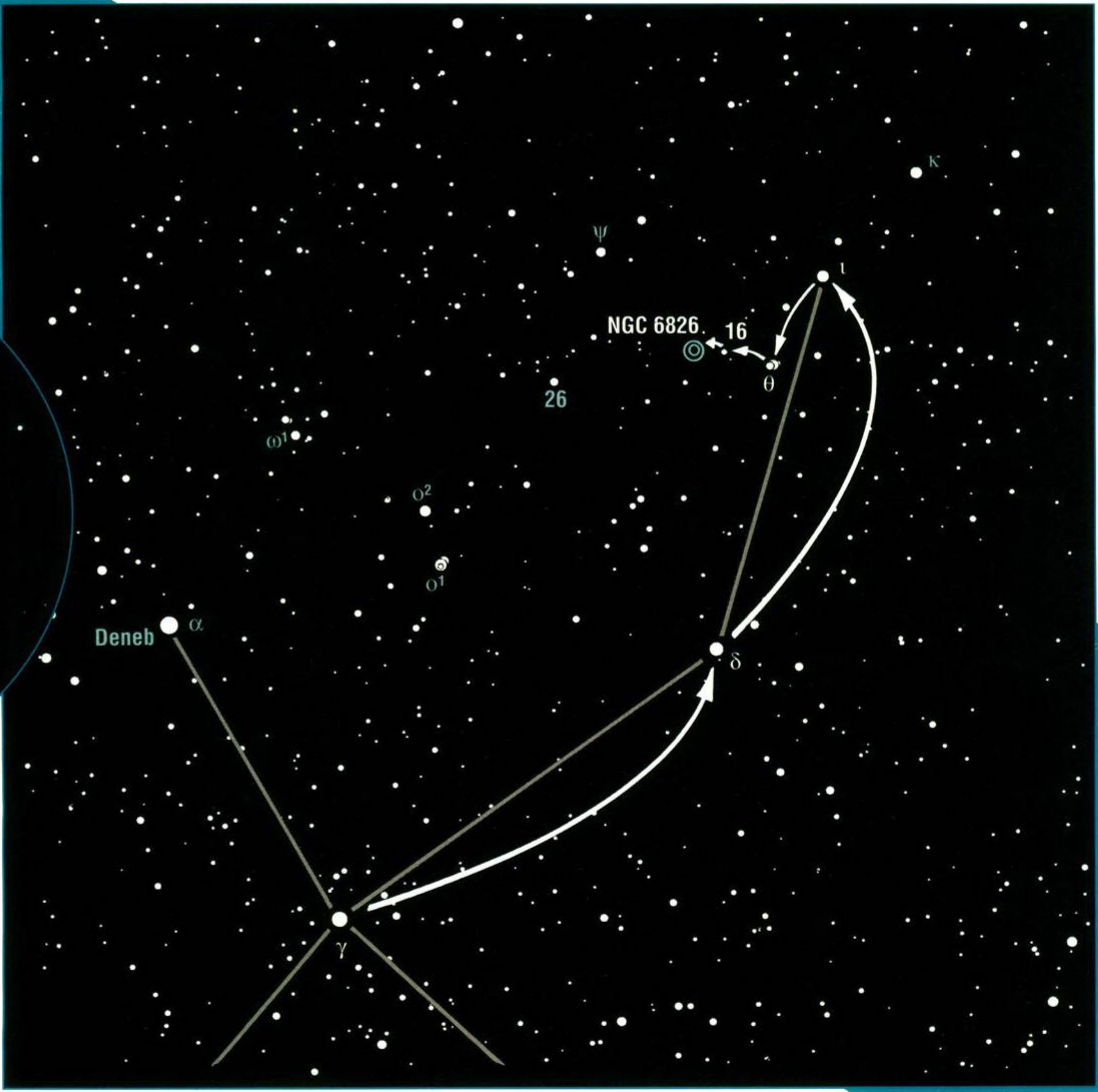
In my detailed plans, I include a description of the object's type, its location, and exactly how I intend to star hop to it. I also add brief comments on any interesting stars or objects along the way. For example, my entry for M31 looks like this:

Object: *Andromeda Galaxy — M31*
Type: *Spiral galaxy*
Constellation: *Andromeda*
R.A.: *0h42.7m*
Dec.: *+41°16'*
Star Hops: *Start at Alpheratz (Alpha Andromedae). Hop 7° east-northeast to Delta Andromedae, then 8° northeast to Beta Andromedae (double star). Next hop 4° northwest to Mu Andromedae and another 3° north-northwest to Nu Andromedae. M31 lies 1.5° due west of Nu.*

If you prefer, describe the star hops in terms of your finderscope's field instead of degrees. Either way, prepare the plan in advance so you don't waste precious time at your observing site fussing with star charts.

A well-crafted, carefully designed plan will help make each trip to a deep-sky wonder a meandering route of memorable celestial scenery.

Another good target to test your star-hopping skills is the galaxy M101 in Ursa Major. Though this hop involves fainter stars than the one to M31 does, the pattern of the stars is easy to recognize. Start with the double star Alcor and Mizar in the handle of the Big Dipper, which lies in the northwest after darkness falls in September. (See the charts on pages 62 and 63.) From Alcor, hop 1.3° east to the star 81 Ursae Majoris (UMa). From there, follow a string of 5th- and 6th-magnitude stars to the southeast. First there's 83 UMa (1.2° away), then 84 UMa (0.9°), and then 86 UMa (1.3°). Then go 0.6° due east to the 7th-magnitude star at the northern end of a string of three stars. M101 lies 1.0° east-northeast of this star.



Our final star-hopping test is the Blinking Planetary Nebula, NGC 6826, in Cygnus, which lies nearly overhead on fall evenings (see charts above). The lead star in this star hop is Sadr (Gamma [γ] Cygni), the middle star in the Northern Cross asterism. From there hop 8° northwest to Delta Cygni and then 7° north-northwest to Iota (ι) Cygni. Next hop 2° south-southeast to the multiple-star system Theta (θ) Cygni, 1° due east to 6th-magnitude 16 Cygni, and finally 0.5° east to NGC 6826.

If you can't find your target after the final hop, try to spot it with averted vision; that is, look to the side of the object's suspected location. If you can't find the object in the finderscope, look through the eyepiece of your telescope and sweep the area slowly and systematically. If the object doesn't come into view after two or three tries, take a break and then move on to the next object on your plan.

By following a patiently planned observing strategy, I am learning the sky the way I always hoped I would. Every night the list of deep-sky marvels I can hop to with ease grows. I enjoy hunting for dim nebulae and galaxies, pausing to view an interesting multiple star or cluster along the way. And once I've hopped to an object a few times, I can find it quickly anytime in the future by just following the familiar pattern of stars.

Whether you're a novice observer standing on the threshold of deep space or a frustrated beginner on the verge of selling your telescope, don't despair. Prepare a deep-sky observing plan and on the next clear, moonless night, go ahead — hop to it. ☐

Marcel W. Bergman is an avid amateur astronomer living in Calgary, Alberta.

HUNTING DOWN THE HELIX

Seek out the sky's largest planetary nebula — and a group of little-known neighbors — in a corner of the constellation Aquarius.

by Phil Harrington

M72

Mag. 9.4

Size 5.9'

by Jack Newton

Planetary nebulae are among the most intriguing of all deep-sky objects. The gently expelled remains of aged stars, these glowing shells of gas are visible in the eyepiece as greenish gray disks of light. A lone giant among planetary nebulae stands out from the throng of its tiny cousins.

The **Helix Nebula** (NGC 7293), a resident of the southwestern corner of Aquarius, is the largest and brightest planetary nebula in the sky. But although the Helix is large and bright, finding it is no piece of cake. Because the nebula lies in a sparse star field, star-hoppers face the challenge of simply getting to the nebula's vicinity. To locate the Helix, begin at the bright star Fomalhaut, found below the nebula in the neighboring constellation Piscis Austrinus. Using your finderscope, slide 4° northwest to 4th-magnitude Epsilon Piscis Austrinus. Crossing into Aquarius, continue 6.5° north-northwest to 5th-magnitude Upsilon Aquarii. Finders reveal that Upsilon is the "knot" in a long, slim "bow tie" of stars that also includes 41 and 47 Aquarii to the west and 66 and 68 Aquarii to the east. The Helix Nebula lies just 1° west of Upsilon.

When you get to the right spot, your challenge may not be over. The Helix is the largest and brightest planetary nebula in the sky. But it is so large — 15' by 12' — that its light is spread over a large area, making individual parts of it appear dim. This is called low surface brightness. In the case of low-surface-brightness objects like the Helix Nebula, binoculars and rich-field telescopes (RFTs) enjoy a great advantage over narrow-field telescopes. Instead of viewing only a small portion of a large target, these instruments view the entire object in a single field. This ability permits much easier isolation of the Helix against the sky. Give it a try. The best view I've ever had of the Helix came a few years ago during the Stellafane convention in Vermont. Through an 8-inch f/4 rich-field Newtonian reflector outfitted with a wide-field eyepiece and a UHC filter, the Helix appeared as a huge, gray smoke ring highlighted by bright and dark streaks.

Two galaxies lying to the east of the Helix serve to further challenge backyard astronomers. The brightest of the two is **NGC 7377**, a type E1 elliptical galaxy. To find it, return to 68 Aquarii in the bow tie asterism. Slide 2.5° southward to a small triangle of 9th-magnitude stars. NGC 7377 lies just south of the triangle. Through my 13.1-inch f/4.5 reflector, NGC 7377 appears pretty faint, relatively small, and perfectly round. A bright, nonstellar core highlights an otherwise uniform disk. The galaxy glows at magnitude 11.6 and

The Helix Nebula

Mag. 6.5

Size 15' by 12'

by Michael Stecker

M30

Mag. 7.5

Size 11.0'

by Jack Newton

spans about 1.5' across, though photographs show its total extent to be 2.2' by 1.8'. About 2° northeast of NGC 7377 lies **NGC 7392**. To locate this 12th-magnitude Sb spiral, return to 66 and 68 Aquarii in the bow tie. Draw a line between the stars and extend it for an equal distance to the southeast — you'll spot NGC 7392 in a low-power eyepiece. Through my 13.1-inch scope, I recorded NGC 7392 as perhaps a little brighter than NGC 7377, with only the vaguest hint of a central core. Photographically, NGC 7392 grows to 2.0' by 1.3', but it impressed me as only about half that size.

A second unusual planetary nebula lies in the extreme western part of Aquarius. You can find the **Saturn Nebula** (NGC 7009) by beginning in neighboring Capricornus. Start at 4th-magnitude Theta Capricorni, found along the top side of a triangle of bright stars. Scan 6° north-northeast to 5th-magnitude Nu Aquarii and then turn westward another degree to find the nebula. On nights of good transparency, the Saturn Nebula is visible as a fuzzy greenish disk of light in steadily supported binoculars and small telescopes. It stands out surprisingly well, partly due to its rather bleak surroundings, but mostly because of a remarkably high surface brightness. This brilliance is caused by unusually strong ultraviolet radiation emitted by its central star. Six-inch and larger telescopes reveal why

The Saturn Nebula

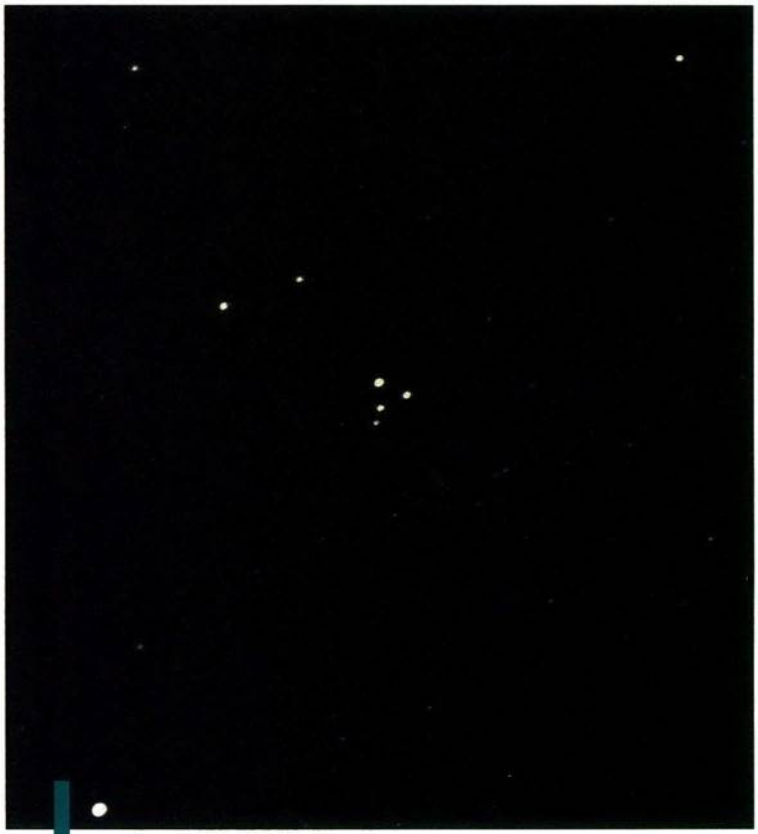
Mag. 8.3

Size 25"

by Jack Newton

DEEP-SKY OBJECTS IN AQUARIUS

Object	R.A. (2000.0)	Dec.	Mag.	Size
M72 (NGC 6981)	20h53.5m	−12°32'	9.4	5.9'
M73 (NGC 6994)	20h59.0m	−12°38'	8.9	2.8'
NGC 7009	21h04.2m	−11°22'	8.3	25"
M30 (NGC 7099)	21h40.4m	−23°11'	7.5	11.0'
NGC 7293	22h29.6m	−20°48'	6.5	15' by 12'
NGC 7377	22h47.8m	−22°19'	11.6	2.2' by 1.8'
NGC 7392	22h51.8m	−20°36'	11.9	2.0' by 1.3'



M73

Mag. 8.9

Size 2.8'

by Martin C. Germano

this unusual nebula gained its nickname. Looking carefully, you can detect two faint lobes protruding from either side of the cloud's round disk. Hence the nickname Saturn Nebula.

Next, we come to two oft-neglected members of the Messier Catalog, the list of objects composed by the French comet hunter Charles Messier. **M72** (NGC 6981) holds the dubious distinction of being the faintest of the 29 globular clusters listed by Messier. Begin your quest for M72 back at Theta Capricorni. M72 lies about two-thirds of the way from Theta to 4th-magnitude Epsilon Aquarii, some 8° to its northwest. An 8-inch telescope reveals stars around the cluster's edges.

While M72 is a bona fide cluster, nearby **M73** (NGC 6994) is a mistake. M73 is listed in both the Messier Catalog and the *New General Catalogue* as an open cluster, with Messier describing it as looking like "a nebula at first sight." M73 is a small Y-shaped asterism of four 11th- and 12th-magnitude stars. Studies indicate that their proximity is also only an illusion. Though they appear within 1.2' of each other, the stars actually lie at widely divergent distances from Earth.

Another lonely member of Messier's catalog is **M30** (NGC 7099). M30 lies just inside the border of neighboring Capricornus. To find M30, begin at Delta and Gamma Capricorni, two stars that form the northeastern corner of the Capricornus triangle. Drop about 2° to the south-southwest and pause at Epsilon Capricorni. From Epsilon, move 4° farther south while watching for a widely separated pair of 6th-magnitude stars. M30 lies just west of 41 Capricorni, the eastern member of the pair. In 1783 William Herschel unmasked the nature of M30 when his mammoth reflecting telescope revealed countless tiny specks strewn across the cluster's disk.

Though our autumn sky may lack the gleaming naked-eye stars of summer and winter evenings, it contains a wide diversity of telescopic treats for amateurs to view. Sure, they may take a little longer to find, but each will pay off richly in the end. ☐

Phil Harrington's last article was "Journey to the Center of the Galaxy" in the July 1991 issue. He is a contributor to the book Stars and Galaxies, ASTRONOMY's Guide to Exploring the Cosmos *(AstroMedia, 1992).*

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Exploring the Autumn Sky

Crisp autumn evenings are perfect for getting acquainted with a flying horse and several "watery" constellations adrift on a vast celestial ocean.

by Deborah Byrd

Cooler weather marks the coming of a new season. The leaves and grass — even the sunlight and sky — seem to take on a more golden hue at this time of year. Night comes earlier now, and the stars of summer slip away to the west while a new company of stars ascends in the east. Every season's night sky is dramatically different. The summer sky — which offers us a glorious edgewise view into the plane of our Galaxy — is rich, remote, and mysterious. The autumn sky has riches and mysteries of its own, but autumn is also a time for more expansive thinking, both into space and back in time.

On a clear September evening, the stars traditionally associated with autumn dominate the eastern half of the sky. Meanwhile, the last of the summer stars sink toward the western horizon. After the Sun goes down, the large constellations Hercules, Ophiuchus, and Sagittarius command your attention in the west. From a dark, rural location when the Moon is out of the sky, search the area around the famous Teapot asterism of Sagittarius for stars, star clusters, and nebulae embedded in the hazy band of the Milky Way. No other region of the sky is so rich in stars. That's because the direction to the star-cluttered center of our Milky Way Galaxy lies just 5° west of the Teapot's spout.

The band of the Milky Way now stretches from the southwestern horizon up to the zenith and then down

AUTUMN'S MOST CONSPICUOUS ASTERISM is the Great Square of Pegasus, a box-shaped foursome which represents the body of the winged horse.

ASTRONOMY: Stephen Walther

ASTRONOMY: Stephen Walther

TWO GRACEFUL STELLAR ARCS constitute the chained maiden, otherwise known as the constellation Andromeda.The constellation contains M31, a bright galaxy.

to the northeastern horizon. If you follow the Milky Way northward from Sagittarius, you'll come first to the small constellation Scutum the Shield, named for the coat of arms of John Sobieski, a Polish king. Though no star in Scutum shines brighter than 4th magnitude, you shouldn't miss this constellation: it contains a particularly brilliant region of the Milky Way known as the Scutum Star Cloud.

Just north of Scutum in the band of the Milky Way is the 0.8-magnitude star Altair. This is the brightest star in the constellation Aquila the Eagle. Altair joins two fainter stars, one on each side, to form a small asterism called the Family of Aquila.

Altair also belongs to a large and very conspicuous asterism containing three stars from three different constellations. With the bright stars Deneb in the constellation Cygnus the Swan and Vega in the constellation Lyra the Lyre, Altair forms the prominent Summer Triangle. This large triangle lies nearly overhead in the early evening hours during September.

Deneb, the brightest star in Cygnus, shines at magnitude 1.3 in the midst of the northern Milky Way. More than a dozen stars seen at various times of the year appear brighter than Deneb, but all of these are brighter because they lie closer to Earth. At a distance of over 1,600 light-years, Deneb lies farther away than any other bright star. To appear as bright as it does, Deneb must generate a prodigious amount of energy — some 60,000 times more than our Sun does.

The bright star Vega and its beautiful constellation Lyra lie to the west of Cygnus and the starry Milky Way band. Vega shines brilliantly at magnitude 0.0 from a distance of 25 light-years. The constellation Lyra, which represents the lyre played by the musician Orpheus, is unmistakable — look for a small parallelogram attached to a tiny triangle of stars.

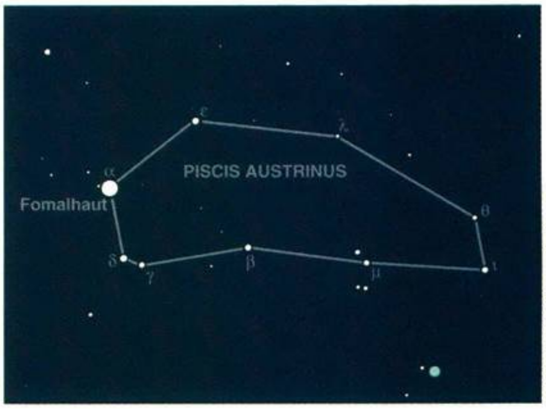
Before leaving the area of the Summer Triangle, take a few minutes to find three tiny constellations nearly hidden among the glittering stars of the Milky Way. Sagitta the Arrow, which consists of four 3rd- and 4th-magnitude stars, actually looks like its namesake. The Arrow is supposedly flying from the bow of Hercules toward Cygnus and Aquila. Delphinus the Dolphin has five primary stars, all of which shine at 4th magnitude. Four of these stars form a conspicuous diamond, while the fifth dangles from the diamond in a way that suggests a dolphin's tail. And finally, right between Sagitta and Cygnus, lies Vulpecula the Fox. When you gaze toward these diminutive patterns of stars, you are looking toward three of the smallest constellations in the sky.

Now turn your attention to the region of the heavens east of the starry Milky Way, to the domain of the autumn constellations. The stars of autumn are prominent in the east on September evenings, but as the night progresses and the starry dome wheels slowly overhead, they move first into the south and finally, shortly before dawn, into the west. The same scenario plays out as the months go by, so that an early evening view in November is identical to a midnight view in September.

The key star figure here is an asterism belonging to the constellation Pegasus the Flying Horse. The asterism has the shape of a large square, with four stars of nearly equal brightness marking its corners. This is the Great Square of Pegasus.

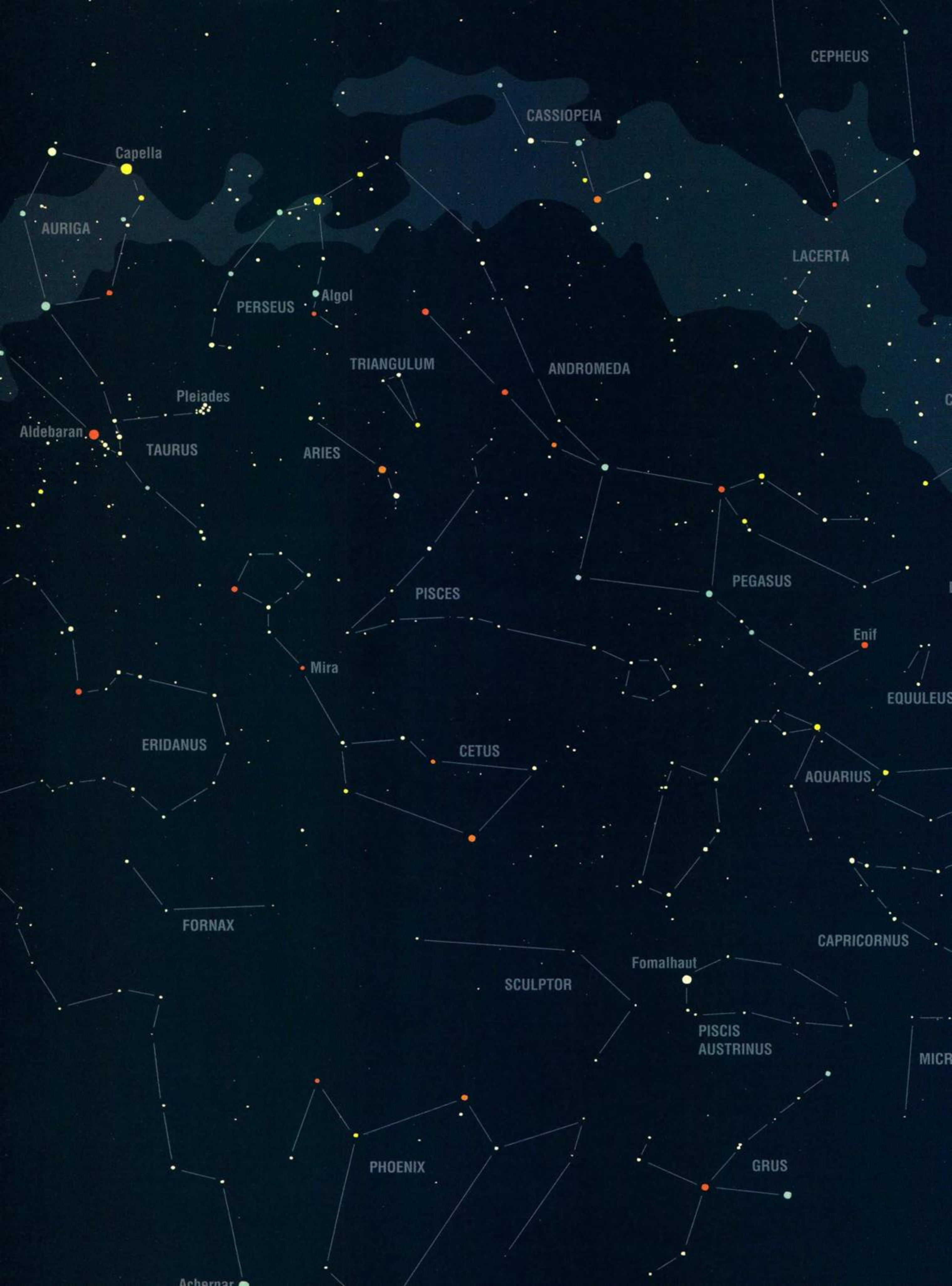
The four stars in the Great Square are Markab (Alpha [α] Pegasi), Scheat (Beta [β] Pegasi), Algenib (Gamma [γ] Pegasi), and Alpheratz (Alpha Andromedae). All shine between 2nd and 3rd magnitude. Alpheratz, at magnitude 2.1, is the brightest of the four stars, though it is not technically part of Pegasus. This star once had the distinction of belonging to two constellations at once, both Pegasus and neighboring Andromeda. In the 1930s, when the International Astronomical Union created official boundaries for all the constellations, they gave this star to Andromeda. It is blue-white in color and located about 70 light-years away.

FIRST-MAGNITUDE FOMALHAUT dominates its constellation, Piscis Austrinus, as well as the region of otherwise barren sky that surrounds it on autumn nights.



ASTRONOMY: Steven Davis

The Great Square represents the body of the Flying Horse. Some say they can't make out a horse in Pegasus' stars, but you might see it as a stick figure. It's easier to see if you remember that the horse is flying upside down across the sky. You might even let Andromeda serve double-duty as the rear legs of Pegasus. The star Enif (Epsilon [ε] Pegasi), west of the Great Square, marks the Horse's nose. This star shines at magnitude 2.4 from a distance of over 500 light-years. An even more remote object, a globular star cluster designated M15, lies just northwest of the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TAURUS
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PEGASUS
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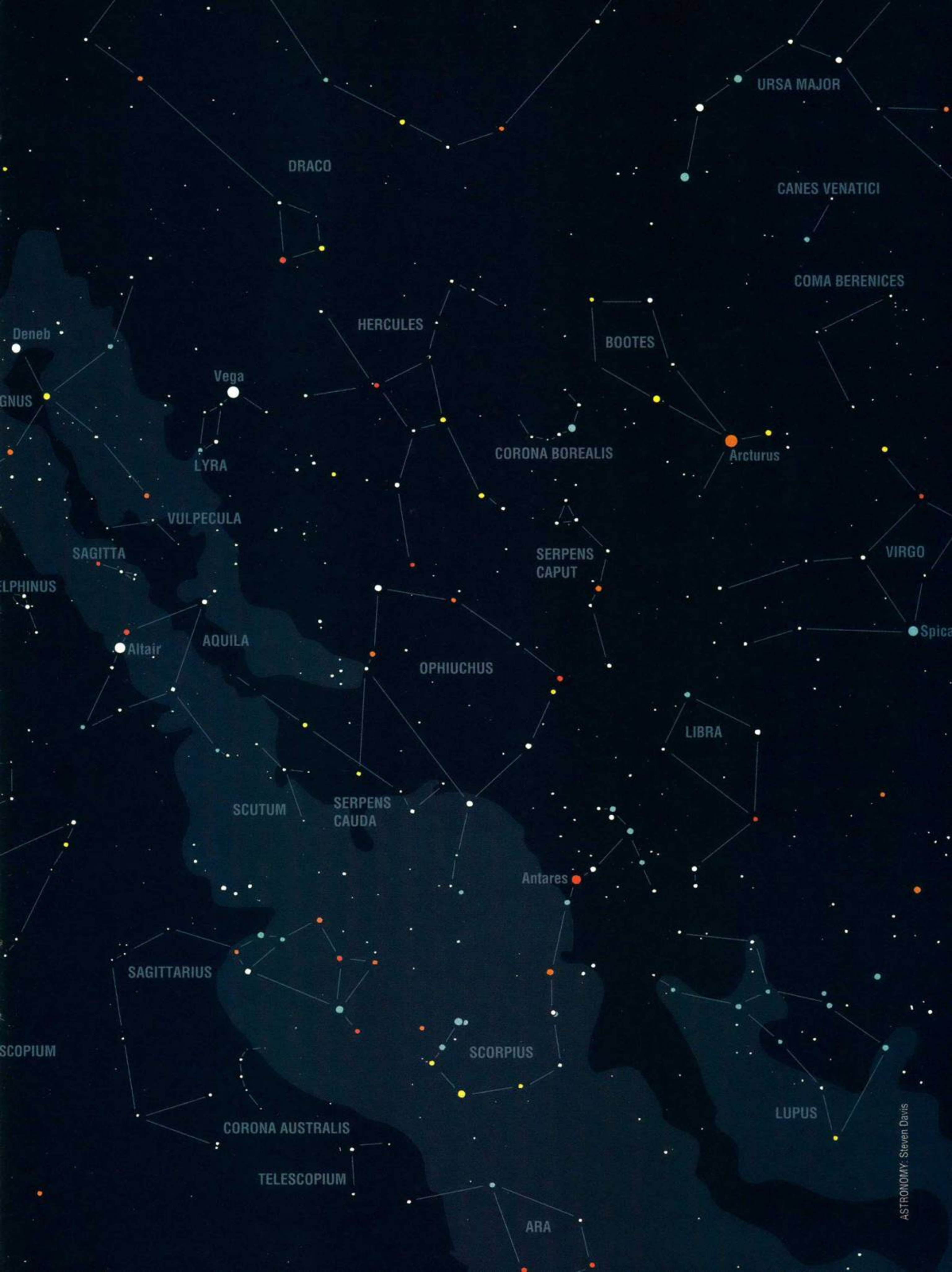
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Antares
SAGITTARIUS
SCOPIUM
SCORPIUS
LUPUS
CORONA AUSTRALIS
TELESCOPIUM
ARA

ASTRONOMY: Steven Davis

Horse's nose. You might glimpse this object with your naked eye on an especially dark night. Also take a few minutes to look for the Little Horse, the constellation Equuleus, which lies less than 10° west of Enif.

The Great Square provides a good test of your eyesight and the night's observing conditions. The brightest star within the Square's boundaries shines at magnitude 4.4, but many more stars here are slightly fainter. It's fun to count how many of them you can see. On a dark night in the country you can expect to see several dozen stars, but many more will pop into view on an exceptionally dark and clear night. Julius Schmidt — a 19th-century astronomer with a reputation for keen eyesight — once counted 102 stars within the Great Square.

ASTRONOMY: Stephen Walther

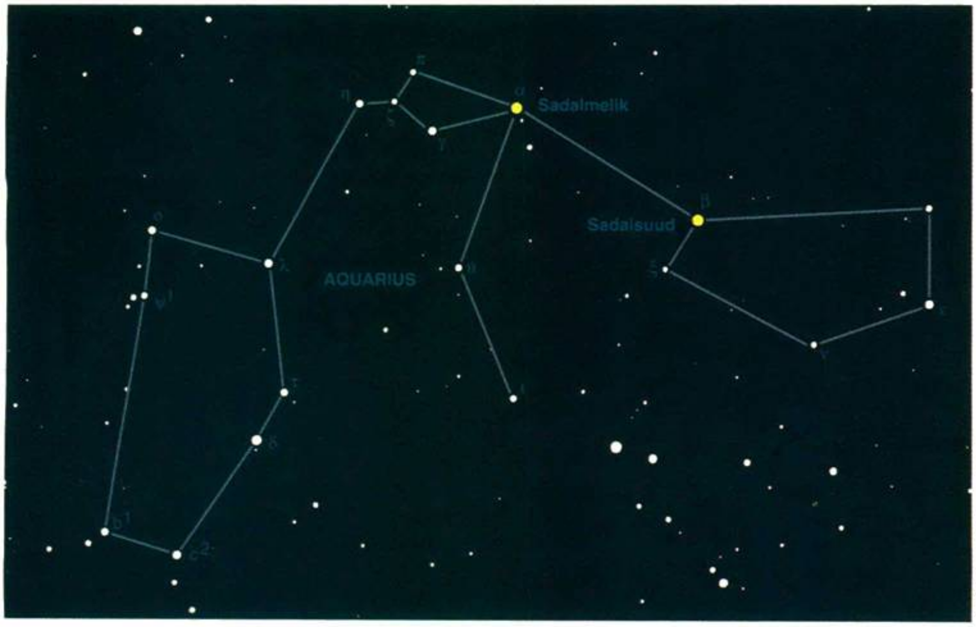
ARIES THE RAM is small but distinct. Look for a trio of bright stars south of Triangulum and Andromeda.

The vision test provided by the Great Square of Pegasus will prepare you for your next visual feat, in which you'll glimpse the most distant object visible to the naked eye. This object is the Andromeda Galaxy in the constellation Andromeda the Chained Maiden. It's also known to stargazers as M31, meaning that it was thirty-first on a list of nebulous objects compiled in the 18th century by one of the first successful comet-hunters, Charles Messier.

First trace the pattern of Andromeda's stars. Its brightest lights are Alpheratz, in the northeast corner of the Great Square, Mirach (Beta Andromedae) and Almach (Gamma Andromedae). In a reasonably dark sky, these three stars highlight two graceful streams of mostly 4th- and 5th-magnitude stars that extend northeastward from the Square. You can find M31 about 10° northwest of Mirach, or about the span of your clenched fist when held at arm's length. All the stars visible to the naked eye belong to our Milky Way, but this object is a separate island of stars. When you gaze upon it, you are looking some 2.2 million light-years beyond the confines of our home Galaxy.

We promised to expand your view not only into space, but also back in time. The constellations Andromeda and Pegasus, along with several other autumn constellations, are part of one of the sky's greatest legends. They bind us to some of our distant ancestors with notions of good and evil, and truth and justice. According to this myth, the vain queen Cassiopeia angered the sea god, Neptune. He ordered her and her husband, King Cepheus, to chain their young daughter, Andromeda, to a rock by the sea. Just as a fearful sea monster, Cetus the Whale, was bearing down to destroy the princess, Perseus the Hero arrived on Pegasus the Flying Horse to rescue her. The gods were pleased, and they later transported the king, queen, princess, hero, horse, and whale to the starry sky, where we see them on autumn nights.

A CELESTIAL OCEAN covers much of the autumn sky, with the large but dim constellation Aquarius the Water Bearer one of its focal points.



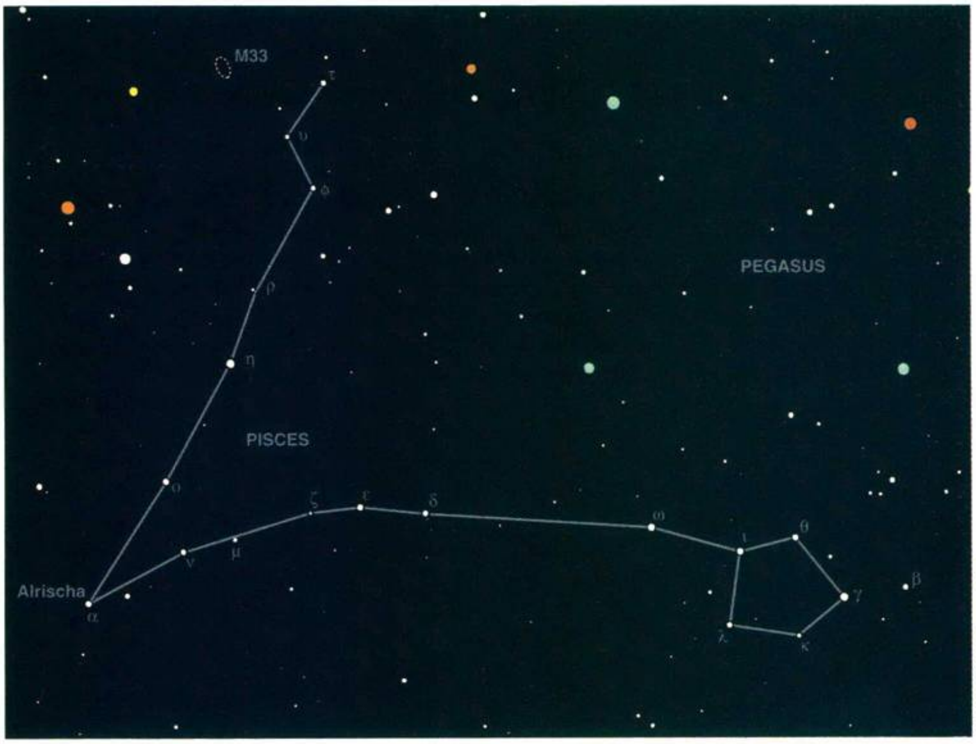
ASTRONOMY: Steven Davis

Southeast of Andromeda is the diminutive constellation Triangulum, which consists mainly of three stars in the shape of an isosceles triangle. These stars are Alpha, Beta, and Gamma Trianguli. The brightest is 3.0-magnitude Beta and the faintest is Gamma at magnitude 4.0. Within this constellation's boundaries lies another nearby galaxy, M33. Like M31, this galaxy belongs to our Local Group, a collection of some three dozen galaxies that spin through eons of time and light-years of space in each other's company. M33 is oriented nearly face-on to our Milky Way. It spans over one degree of sky and has a low surface brightness, which makes it extremely hard to spot with the naked eye. You'll need the clearest and darkest of skies to spot it. One way to increase your chances is to use averted vision — instead of looking directly at the object, look for it out of the corner of your eye. That way you'll be using the cells in your eyes that are most sensitive to faint light, the rods.

Immediately south of Triangulum you'll easily find the zodiacal constellation Aries the Ram. It contains three bright stars — the brightest shines at 2nd magnitude, the next at 3rd magnitude, and the faintest at 4th magnitude — that form a crooked line extending about 5°. A fourth star located 10° northeast of the brightest star completes the pattern.

Now you may need to squint a little. Our next constellation contains no star brighter than 4th magnitude, but it is so graceful and lovely that you'll enjoy tracing its entire outline on the starry dome. The constellation Pisces the Fish consists of two streams of stars in a V-shape running along two sides of the Great Square. One stream is known as the Northern Fish. The other, called the Southern Fish, ends in a pretty circular asterism called the Circlet.

The vertex of the V is Pisces' third-brightest star, Alrischa (Alpha Piscium), whose name derives from an Arabic word meaning "the cord." On old maps of the heavens, this star was seen as the cord that binds the two fish together by their tails. Alrischa shines at magnitude 3.8 from a distance of 100 light-years.



ASTRONOMY: Steven Davis

A PAIR OF FISH under the name Pisces cavort in the autumn sky. You can trace this constellation's pattern by first finding a circle of stars — just visible to the naked eye — immediately south of Pegasus' Great Square.

So far we've concentrated on the sky to the west, east, and nearly overhead. When you look toward the southern sky, you'll find it relatively empty of stars, and for good reason. To gaze southward on autumn evenings is to look away from the star-rich disk of the Milky Way, out our Galaxy's "south window" and toward intergalactic space. Several more members of our Local Group lie in this direction, but these galaxies are too faint to glimpse with the naked eye. Still, it's good to cast your mind outward toward these collections of stars, which are our nearest neighbors in the vast universe.

There is a single bright star in the southern sky in autumn. It's called Fomalhaut, and it resides in the constellation Piscis Austrinus the Southern Fish. Fomalhaut is sometimes called "the lonely one" or "the solitary one." It makes a rather low arc across the southern sky during the course of the night, but you'll have no trouble identifying it in an expanse of sky devoid of other bright stars. Fomalhaut shines at magnitude 1.2 and is located only 22 light-years away.

Now tune your eyes to faint stars again, to see some of the other constellations in the southern sky. Look for the zodiacal constellation Aquarius, the Water Carrier, located above Piscis Austrinus in the south. This constellation is large and fairly difficult to trace, but it has an identifiable asterism, a compact Y-shaped grouping of stars called the Water Jar. If your sky is reasonably dark, you can see a faint stream of stars zigzagging from the Water Jar down toward Piscis Austrinus. These stars represent water flowing into the open mouth of the Southern Fish.

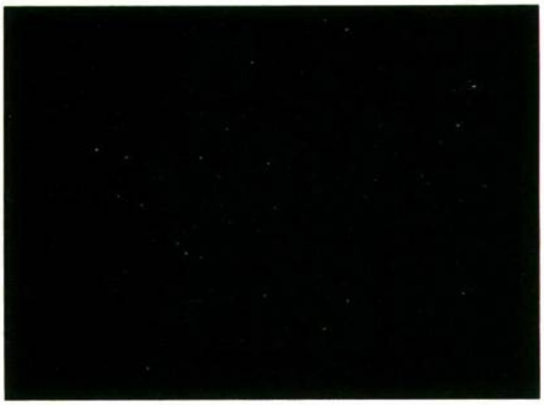
Aquarius was clearly considered a bringer of good fortune by the early Arabian stargazers. Its brightest stars — both shine at 3rd magnitude — are Sadalmelik (Alpha Aquarii), whose name means "the lucky one of the king," and Sadalsuud (Beta Aquarii), whose name means "the luckiest of the lucky."

Capricornus, another zodiacal constellation, lies northwest of Piscis Austrinus. This constellation represents a Sea Goat, but its shape more nearly resembles that of an arrowhead. Algedi (Alpha Capricorni), whose name means "goat," lies at the northwest corner of the arrowhead. It is a wide, naked-eye, double star. This is not a physical pair, but merely two stars that happen to lie along the same line of sight. The brighter component lies about 120 light-years away, while the other is over ten times more distant. Look also for the star Deneb Algedi (Delta [δ] Capricorni), whose name means "goat's tail."

Many of the autumn star figures — Cetus, Delphinus, Pisces, Piscis Austrinus, Aquarius, and Capricornus — have in common that they are "water" constellations. The autumn sky contains a celestial ocean, whose origin stems from the time several thousand years ago when the Sun lay in front of these stars during the rainy season (late winter and early spring). Each year, as an autumn hush falls over the land, this great mythological ocean wheels across the evening sky. It occupies the same region of the heavens that serves for us as a "window" to intergalactic space.

How did the ancient stargazers perceive the ocean in the autumn sky? Was it merely fanciful to them? Or were they like us in using these stars as signposts to their own cosmology, the grand cosmic setting in which they lived out their entire lives? What did they really believe, and what will our descendents believe when they gaze toward these stars in another thousand years? Contemplate the answers to these questions while the autumn constellations still dominate the sky, because it won't be long before winter's stars ascend to take their place. ☐

CAPRICORNUS THE SEA GOAT is another watery constellation visible this time of year, but its shape more closely resembles that of an arrowhead.



ASTRONOMY: Stephen Walther

Deborah Byrd writes ASTRONOMY's monthly sky column "Eye on the Sky." Her last feature article was "Exploring the Summer Sky" in the June 1992 issue.

GETTING THE EXPOSURE RIGHT

Not too bright, not too dark, but just right. Learning to get well-exposed negatives or slides is the first step toward great astrophotos.

by Alan Dyer

Photographing the sky is a craft. The satisfaction you get from that craft comes not only from the fine images you create but also from the skills you acquire in learning to produce those images. One of the skills every astrophotographer soon develops is the ability to judge what exposures to use.

Photographers of daytime scenes have an arsenal of technological wonders to help them get the right exposure — light meters, auto-exposure cameras, programmable cameras. Today's cameras do practically all of the thinking for you. But with night-sky photography, light meters don't work — there isn't enough light for a meter to respond to.

Instead, you have to do the thinking. It's more challenging, but getting good results is rewarding.

You Can't Go Wrong

Beginners often worry too much about getting perfect exposures. But here's a secret: for most astrophoto subjects there is no single "correct" exposure. Only three types of celestial objects require that exposures be fairly precise: the Sun, the Moon, and the bright planets. You can get good shots of those objects by following some basic guidelines and knowing the fundamentals of f/ratios and film speeds.

With every other celestial subject, exposures can vary over a wide range and still produce pleasing results. For example, in the series of photos on pages 82 and 83, which one is the best? Is it the one we've marked as the correct exposure? You might prefer the underexposed version or the overexposed one.

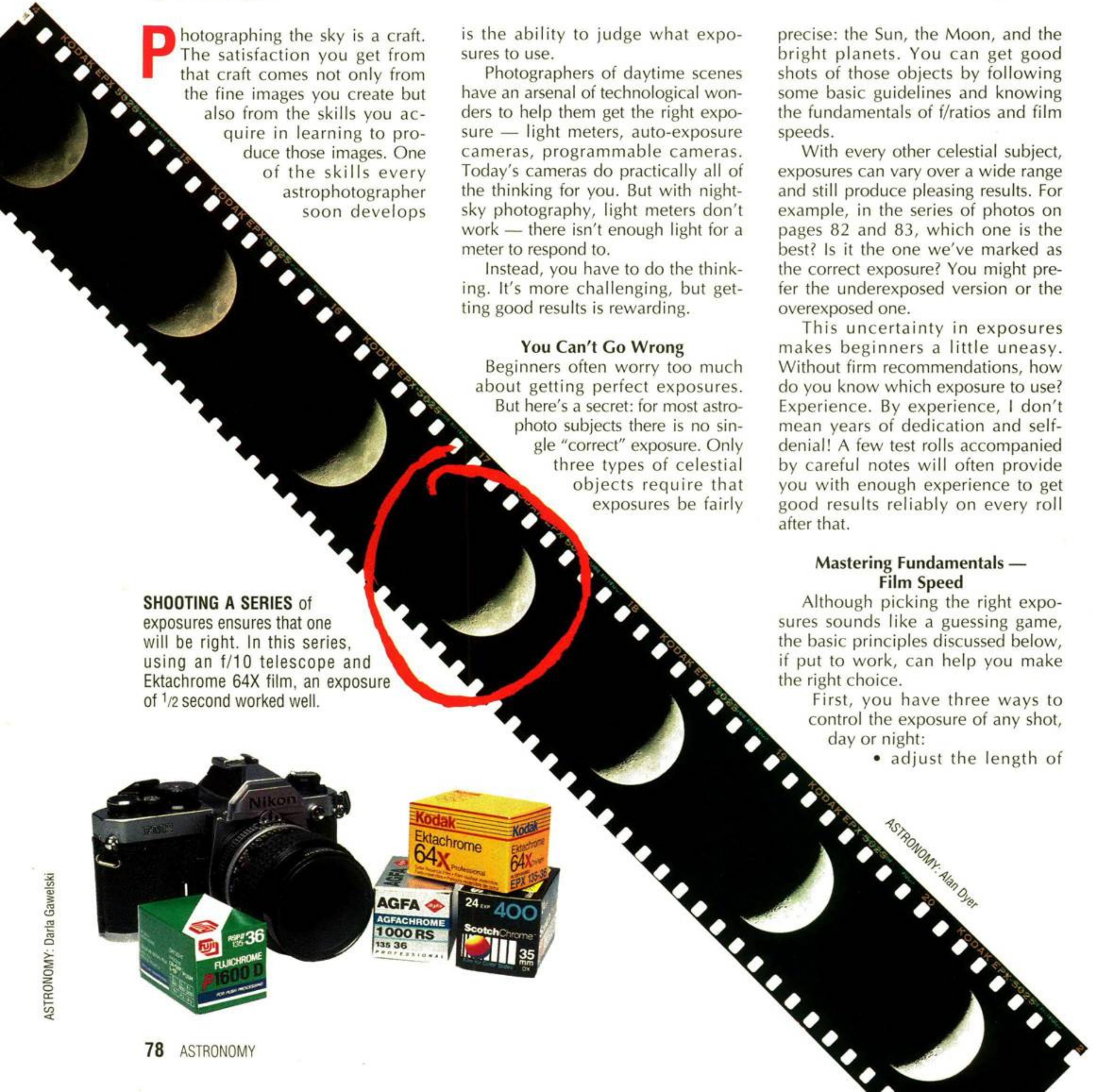
This uncertainty in exposures makes beginners a little uneasy. Without firm recommendations, how do you know which exposure to use? Experience. By experience, I don't mean years of dedication and self-denial! A few test rolls accompanied by careful notes will often provide you with enough experience to get good results reliably on every roll after that.

Mastering Fundamentals — Film Speed

Although picking the right exposures sounds like a guessing game, the basic principles discussed below, if put to work, can help you make the right choice.

First, you have three ways to control the exposure of any shot, day or night:

- adjust the length of



SHOOTING A SERIES of exposures ensures that one will be right. In this series, using an f/10 telescope and Ektachrome 64X film, an exposure of 1/2 second worked well.

ASTRONOMY: Alan Dyer

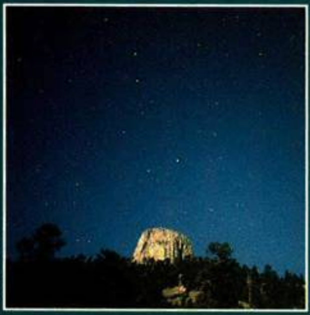
ASTRONOMY: Daria Gawelski

CAMERA ON TRIPOD

ASTRONOMY: Darla Gawelski

Josh Vaughn

Jay Brausch


Jerry Schad

Joe Haberthier and Marcy Flint

TWILIGHT SCENES

Focal lengths	28 to 135mm
F/ratios	f/2 to f/4
Film speeds	ISO 64 to 200
Exposure range	1 to 30 sec.

For shots of the twilight colors themselves or for the Moon and planets in twilight, use slow- to medium-speed film and exposures from 1 second when the sky is bright to as long as 30 seconds or more during the last vestiges of twilight. Bracket exposures over a wide range.

AURORAE

Focal lengths	8 to 50mm
F/ratios	f/1.4 to f/2.8
Film speeds	ISO 200 to 1600
Exposure range	5 to 30 sec.

Aurora exposures depend on the brightness of the display and the brightness of the sky. Bright aurorae require no more than 5 seconds at f/2 with ISO 400 to 1600 film. Faint aurorae require 20 to 30 seconds and a dark sky. Bracket widely. If it's a rare bright display, don't spare the film.

CONSTELLATIONS

Focal lengths	28 to 135mm
F/ratios	f/2 to f/2.8
Film speeds	ISO 400 to 3200
Exposure range	10 to 50 sec.

To keep stars looking starlike, use exposures no longer than 20 seconds with a 50mm lens (40 to 50 seconds with wide-angle lenses, 5 to 10 seconds with short telephotos). Use ISO 1600 to 3200 film to record as many stars as possible in that time limit. Stop lens down to f/2 or f/2.8.

STAR TRAILS

Focal lengths	8 to 50mm
F/ratios	f/2.8 to f/5.6
Film speeds	ISO 200 to 400
Exposure range	5 to 60 min.+

Use a medium- to high-speed film (but not ultrafast ISO 1600 to 3200 film), f/ratios of f/2.8 to f/5.6 (but not ultrawide apertures of f/1.4 or f/2) and exposures from 5 minutes to an hour or more. Maximum exposure time depends on sky darkness (the darker the better) and desired effect.

time the shutter remains open (the shutter speed) or

- adjust the amount of light coming through the lens (by varying its aperture, or f/ratio) or
- select a film with a greater or lesser sensitivity to light (a value given by the film's ISO number).

Choosing the right film for the subject is an important part of building your astrophoto skills. Faster films are more sensitive and require shorter exposures, but produce grainier images. In general, slow, fine-grained films (ISO 25 to 100) are reserved for bright subjects such as whole-disk views of the Sun and Moon. Moderate-to-fast films (ISO 200 to 400) are good for dim subjects such as aurorae, starfields, and the Moon and planets photographed at high magnifications. Ultrafast ISO 800 to 3200 films are excellent for faint targets such as deep-sky objects photographed through a telescope.

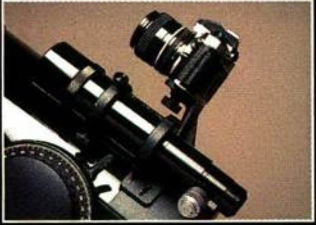
For the purposes of calculating exposures, the important rule to remember is that when you double the film speed, you cut the exposure time in half. For example, if your test rolls tell you that an ISO 100 film requires 1/60 second for a good shot of the Moon, an ISO 200 film will need only 1/125 second. An ISO 400 film would need 1/250 second, and so on.

Going the other way, an ISO 50 film would need 1/30 second, while an ultra-fine-grained ISO 25 film would require a 1/15-second exposure. It's a simple principle to remember, which is a good thing, because you'll rely on it every time you work out exposures for each shooting session.

More Fundamentals — F/ratios

Once you've elected to use a certain type of film, shutter speeds and f/ratios become your main methods for varying exposures. When you are using the camera's own lens you can vary the lens aperture. This is done using the ring marked in the following increments: f/1.4 (in the case of fast lenses), f/2, 2.8, 4, 5.6, 8, 11, 16, and so on. These numbers seem arbitrary but they actually do mean something. They represent the focal length of the lens divided by the aperture. This is called the focal ratio or f/ratio. A 50mm lens set to f/2 has an effective aperture of 25mm

PIGGYBACKED CAMERA



ASTRONOMY: Darla Gawelski

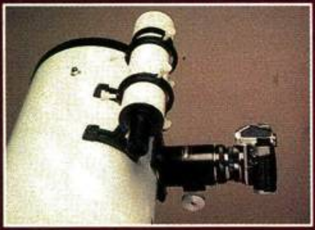
Terence Dickinson

STARFIELDS AND NEBULAE

Focal lengths	8 to 400mm
F/ratios	f/2 to f/4
Film speeds	ISO 200 to 800
Exposure range	5 to 60 min.+

Use a medium- to high-speed film (but not an ultrafast ISO 1600 to 3200 film), f/ratios of f/2 to f/4, and exposures from 5 minutes to an hour or more. Maximum exposure depends on sky darkness (the darker the better). "Correct" exposure for your site and favorite film will require some trial and error.

THROUGH THE EYEPIECE



ASTRONOMY: Darla Gawelski

Howard Zeh

THE MOON

Focal lengths	600 to 2,000mm
F/ratios	f/4 to f/16
Film speeds	ISO 25 to 200
Exposure range	1/500 to 1/2 sec.

Exposures vary with lunar phase. For the Full Moon, try 1/60 second at f/11 with ISO 50 film. Double the exposure for each lesser phase: gibbous phase = 1/30 second, Quarter = 1/15, wide crescent = 1/8, thin crescent = 1/4. For earthshine photos, try 10 to 60 seconds with ISO 200 to 400 film.

Kim Zussman

LUNAR CLOSE-UPS & PLANETS

Focal lengths	5,000 to 30,000mm
F/ratios	f/32 to f/128
Film speeds	ISO 200 to 1600
Exposure range	1/2 to 10 sec.

Close-ups of the lunar terminator require exposures from 1/2 to 2 seconds, while Venus requires 1/4 to 1 second, Jupiter and Mars 1 to 4 seconds, and Saturn 4 to 8 seconds. Use fast film to keep exposures to a minimum and enough focal length to keep the image size large enough to record detail.

David Ratledge

DEEP-SKY OBJECTS

Focal lengths	600 to 2,000mm
F/ratios	f/4 to f/10
Film speeds	ISO 400 to 3200
Exposure range	5 to 120 min.+

Use fast or ultrafast films and exposures as long as local sky conditions will allow. Five to 10 minutes at f/10 with ISO 3200 film will suffice for bright deep-sky objects. If skies permit, expose even longer to record maximum detail. Test rolls will help determine your site's sky fog limit.

across. Stop it down to f/4 and its internal diaphragm closes to 12.5mm across.

The smaller the f/number, the wider the aperture. The wider the aperture, the more light the lens lets through, and the shorter the required exposure. In fact, with each incremental step down the scale (say from f/2.8 to f/2) the area (not the diameter) of the lens aperture doubles, letting through twice as much light. Opening up one f/stop produces the same result as doubling the exposure time. For example, if your Moon shots turn out fine using a 1/60-second exposure at f/11, then at f/8 the exposure will be 1/125 second.

When you are shooting directly through a telescope, you no longer have the freedom to vary the f/ratio. The f/ratio of your scope is fixed; perhaps it's an f/4 scope or an f/6 or f/10. In this case, the only way to vary the exposure (short of putting in a different speed film) is to adjust the shutter speed.

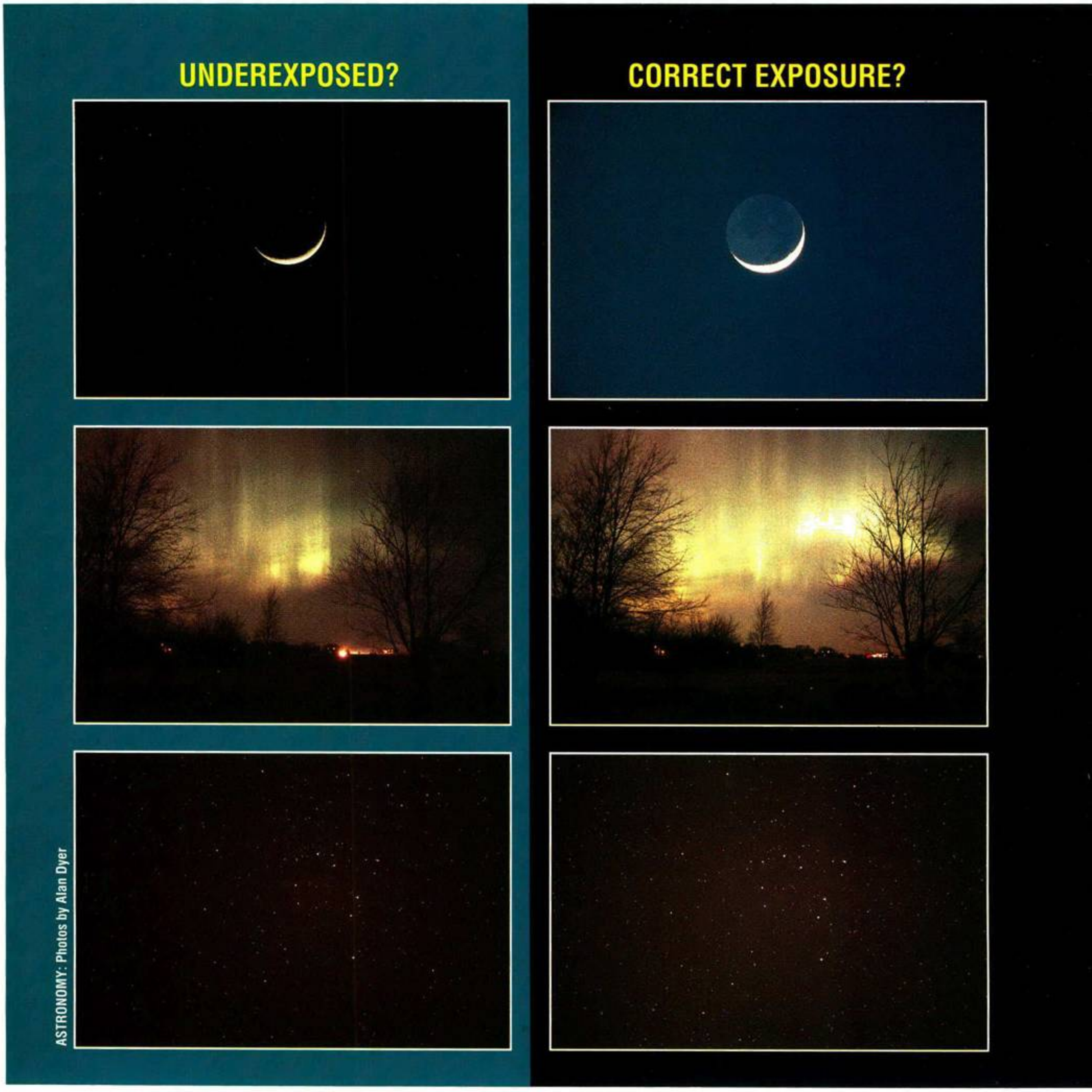
The Moon and Worlds Beyond

You'll use the basic relationships between ISO speed, f/ratio, and shutter speed every time you take pictures of the Sun, Moon, and planets. Because the Moon changes phase, lunar exposures vary over a wide range but all are shorter than you might think — after all, the Moon is just a large sunlit rock.

For shots of the Full Moon, a good starting point is 1/60 second with ISO 50 film, a suitable film for such a bright object. This assumes an f/ratio of f/11, close to the f/10 focal ratio of many Schmidt-Cassegrain telescopes.

If you have an f/16 telescope (or something close to it, such as an f/15 refractor) you would use 1/30 second. If you have a faster telescope you can use a faster shutter speed. As in the example above, with an f/8 scope, use 1/125 second. At f/5.6 you would use 1/250 second. If you have an f/5 or f/6 scope, 1/250 should work fine.

Phases less than Full require longer exposures. Luckily, you don't have to guess. Just follow this simple rule: Each phase less than Full requires a doubling of exposure. If 1/60 second works for a Full Moon, then 1/30 should be fine for a gibbous



ASTRONOMY: Photos by Alan Dyer

Moon. A First or Last Quarter Moon will require 1/15 second, while a wide crescent such as a 5- or 6-day-old Moon will need 1/8 second. A thin crescent needs the longest exposure, about 1/4 second, though 1/2 second wouldn't hurt. (For more information about lunar photography, see "Staging a Moon Shot," August 1992.)

The 1/4-second recommendation for a crescent Moon exposes the lit crescent correctly. If you want to bring out the dim earthshine on the dark part of the Moon, you'll need a much longer exposure and a faster film. If you are shooting through a telescope, try ISO 200 or 400 film and a 10- to 60-second exposure.

To get shots of the Sun through a telescope or long telephoto lens, you must use a safe filter over the front aperture of the scope or lens. The exposure will depend on the density of the filter, but for starters try the same exposure you use for a Full Moon.

Planets pose a special challenge. Though their disks are relatively bright, they are small. If you shoot directly through a telescope, you'll get nothing more than a bright dot. To magnify a planet's disk enough to record detail, you need to employ a camera adapter that allows you to place an eyepiece between the telescope and the camera. Using this "eyepiece projection" technique you can get a planet disk about 2 to 4 mm across on the film frame. At the f/50 to f/100 f/ratios produced by eyepiece projection, planet exposures run in the 1/4- to 8-second range.

Venus is the brightest planet and can be snapped through a telescope with exposures as short as 1/4 second with ISO 100 film. Jupiter and Mars require shutter speeds 8 times longer (equivalent to three f/stops). This puts the exposure at around 2 seconds. Saturn is dimmer still and requires 4- to 8-second exposures. But in all cases, take lots of exposures. (For more details about planetary photography, see "How to Take a Planetary Portrait," July 1990.)

Staying Out of the Fog

If you want great shots of stars and constellation patterns, simply load in a roll of fast film, put your camera on a tripod, open the lens to

OVEREXPOSED?

CRESCENT MOON: Which is the best exposure? A 1/8-second shot (left) records the lit crescent. A 10-second exposure (middle) picks up the earthshine. In a 30-second shot (right), the twilight sky brightens to daylight levels. All were taken on ISO 400 film with a 94mm f/7 scope.

AURORA: Shorter exposures (5 seconds, left) freeze the moving curtains. Longer exposures (10 to 20 seconds, middle) blur the curtains but produce a brighter image. Go too long (30 to 40 seconds, right) and the aurora and sky begin to bleach out, especially with the ISO 1000 film used here.

STARFIELDS: Two minutes on ISO 400 film with a piggybacked 180mm lens at f/2.8 (left) records the Coma Berenices star cluster with a dark sky. After four minutes (middle) sky fog begins to intrude. At eight minutes (right) the sky is a brownish red from skyglow.

f/2 or so, and open the shutter for 20 seconds. If your sky is fairly dark, you'll record stars fainter than you can see with your naked eye.

To keep the stars looking starlike, don't go much longer than 20 seconds. Beyond that, the apparent motion of the sky will trail the stars into streaks. Because nature itself poses a time limit to this type of photography, you control exposure by selecting the lens aperture and the film speed. In this case, use an ISO 1600 to 3200 film. That way you'll pick up as many stars as possible during the limited time exposure.

As for aperture, most starfield astrophotos benefit from using a wide aperture. This is the same thing as saying "Use a fast lens." However, even if you have a fast f/1.4 lens at your disposal you're often better off stopping it down to f/2 or f/2.8. This will improve the sharpness of stars in the corner of the frame, reducing the image-distorting aberrations that many ultrafast lenses are prone to when used wide open.

If you go longer than 20 seconds, stars will trail across the film. To purposely create a star trail photo, use an ISO 200 to 400 film, stop the aperture down to f/4 or f/5.6, and open the shutter for 10 minutes to an hour. How long you can go depends on the darkness of your sky. Light pollution will eventually fog the film, making the sky look an ugly shade of brown or green.

Starfield shots longer than a minute or two are out of the question for city dwellers, but from a decent suburban location you should be able to go several minutes. From a dark rural site you may be able to leave the shutter open for an hour or more.

The same time limits apply if you attach a camera to the side of a telescope. The telescope's drive will track the camera across the sky, giving you pinpoint stars no matter what the exposure duration. This type of piggyback photography yields superb images of starfields and the Milky Way but is best done from a dark-sky site. (See "Give Your Camera a Piggyback Ride," January 1992.)

With an f/2.8 lens and ISO 400 film, a five-minute exposure will record lots of stars and some of the brightest nebulae. You could use an ISO 800 or 1600 film to grab even fainter objects but at some sacrifice of film grain. Conversely, you could leave the shutter open longer. In a dark sky, you should be able to go 20 to 30 minutes at f/2.8 with ISO 400 film and still retain black skies. But at some point you'll run into your site's sky fog limit. Longer exposures produce brighter skies, not more stars or nebulosity.

You'll also run into sky fog when you shoot deep-sky objects through your telescope using a technique called prime-focus photography. But the time limit is much longer. Telescopes are generally no faster than f/4, with f/6 a common f/ratio for a deep-sky photo telescope. Using these slower f/ratios and ISO 400 film and shooting from a good suburban site, sky fog won't intrude for 20 to 30 minutes. Under very dark skies, you could go all night.

Ultrafast ISO 3200 films are great for prime-focus shots, especially with slower f/8 or f/10 telescopes. They keep exposure times to bearable lengths (5 to 15 minutes). But even these incredible films can't avoid the sky fog limit. Ultrafast films simply get you to that limit sooner.

With deep-sky photography through a telescope, as with piggyback photography, the correct exposure is the longest one you can use without incurring objectionable sky fog. Where that exposure limit lies will depend on your site. This is why no one can tell you what the "right" exposure is. As with all types of astrophotography, the best advice is — shoot test rolls. They will give you valuable experience that no amount of expert advice or exposure tables can match. Gaining that experience and putting it to good use is part of the satisfaction of doing astrophotography. ☐

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U.S. Patent 4,473,636

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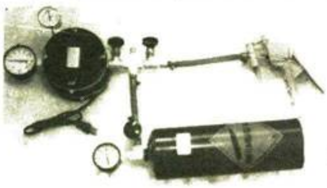

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U.S. Patent 4,448,500

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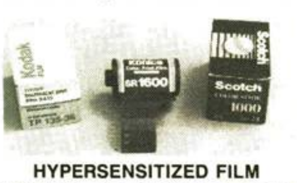

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#1697 Computer Drive, 747 object computer memory, automatic slewing to desired object **$595**
8,000 Object CNGC Library .. **$99** Polar alignment finder .. **$99**
Optional optical encoders for #1697 drive **$299**

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NEW MEADE 8'' LX200 TELESCOPES

See the Meade ad in this magazine for full specifications and details. **LX100 Drive**, 2X, 32X speed control with PPEC (Permanent Periodic Error Correction "Smart Drive") and dual-axis hand controller. **LX200 Drive**, Full electronic control with PPEC, 747 object computer memory and automatic computer controlled slewing to desired object. *NOTE:* A wedge is **not** needed for visual observing with the LX200 Drive.

8'' **LX100** Schmidt-Cassegrain with wedge (add $105 P&S) . **$1695**
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*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated shipping charge to the price. LUMICON showroom prices are $96 higher.

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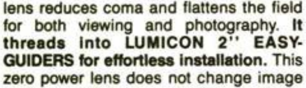
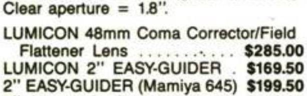
Ultima 8, 11 .. **add $25**, C-14 .. **add $75**

COMA CORRECTOR



Coma 1 inch off-axis 17½'' f/4.5



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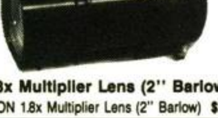
2'' DELUXE BARLOW



1.8x Multiplier Lens (2'' Barlow)

LUMICON 1.8x Multiplier Lens (2'' Barlow) **$235.00**

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Protect the optics of your 8-14'' Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

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FROM $59.50

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Select your desired base-plate shape! Flat, 7'' OD, 9½'' OD, 12½'' OD, 16'' OD, 21'' OD.

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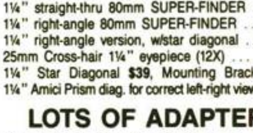
LUMICON 50mm, 80mm SUPER-FINDER™



Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

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2'' long extension for 2'' eyepieces* .. **$26.00**

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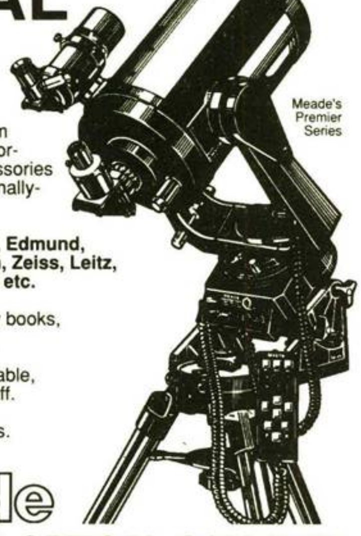

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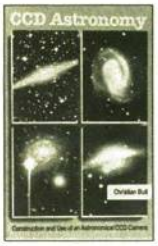

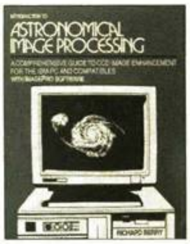

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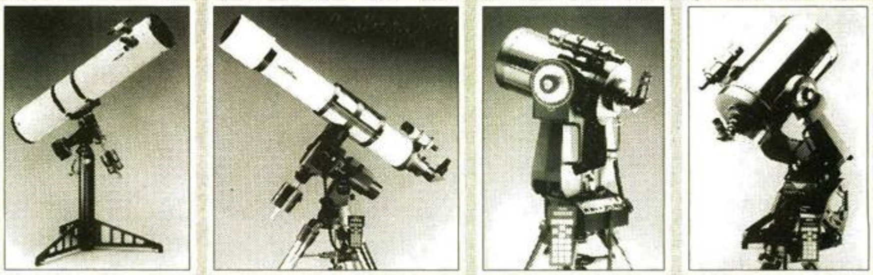
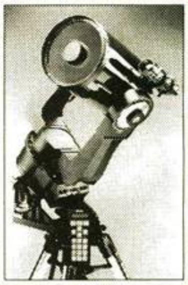


Shown: several of Meade's new APD telescopes



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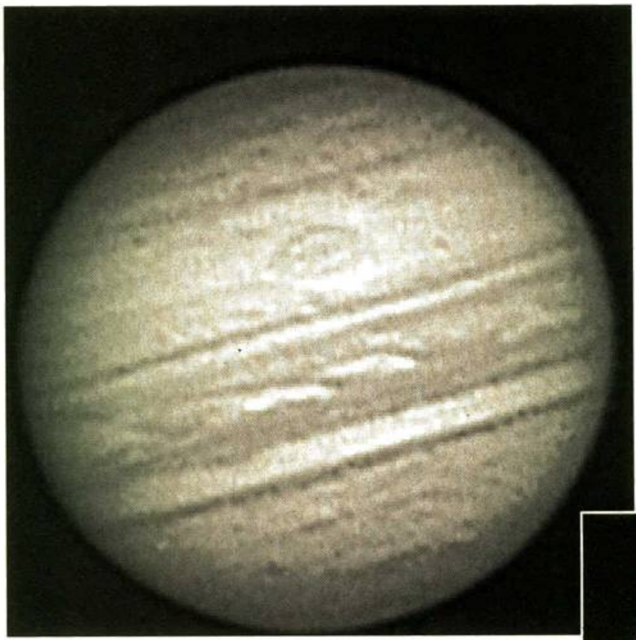
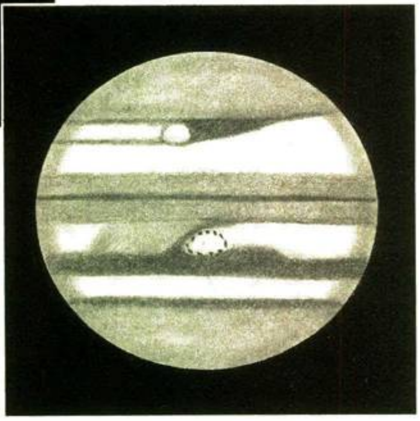




JOVIAN BELTS AND FESTOONS were visible in the eyepieces of backyard telescopes during early 1992. Greg Terrance's CCD image of the mighty planet (left) shows the Red Spot's appearance on March 23. Jose Olivarez sketched the planet with an 8-inch scope two days earlier, capturing two bright ovals on Jupiter's disk (below).

Although it is currently in conjunction with the Sun and therefore temporarily invisible, Jupiter in past months has given backyard observers a spectacular show. The planet's bands, belts, festoons, spots, and other cloud features have provided skywatchers armed with even small scopes the opportunity to see features change nightly on a world eerily different than our own.

Jose Olivarez of Wichita, Kansas, Jupiter recorder for the Association of Lunar and Planetary Observers (ALPO), reports outstanding features occurring in the Jovian cloudtops last winter and spring. "The Great Red Spot appeared faint in January and February but intensified in March," says Olivarez. "The spot appeared as a well-defined ellipse about 22° long with its longitude centered at about 32°. It had a distinct light orange color." The Red Spot was only the tip of the iceberg, however. Olivarez reports observing blue festoons in the planet's equatorial zone. These appeared very bluish and were actively changing in March, when Olivarez observed them with an 8-inch reflector.

Jupiter's equatorial zone offered its share of activity in a group of white ovals observed by Olivarez and other members of ALPO. On March 14, Olivarez recorded an especially bright oval that appeared as the brightest feature on the planet. ALPO observers spotted it again on March 21 when it persisted as the brightest feature on Jupiter.

. . . And a Jovian Eclipse. "I never would have guessed that I could see an eclipse by simply driving 50 miles from home," writes Patrick Wiggins, a staff member of the Hansen Planetarium in Salt Lake City. "But an article in ASTRONOMY alerted Siegfried Jachmann, a fellow member of the Salt Lake Astronomical Society, to the fact that syzygy would occur between the Sun and the Galilean satellites Europa and Ganymede on the morning of March 22, 1992. Given the exact time and appropriate weather conditions, we would be able to see Ganymede slowly dim as Europa's shadow swept across its surface."

The event looked daunting at first, however. Says Wiggins: "The morning of the 21st dawned to heavy clouds. At 8 p.m. that evening, after a day filled with rain, the weather had cleared slightly. By 10:30 p.m., the situation looked mediocre at best, but we gambled and decided to go."

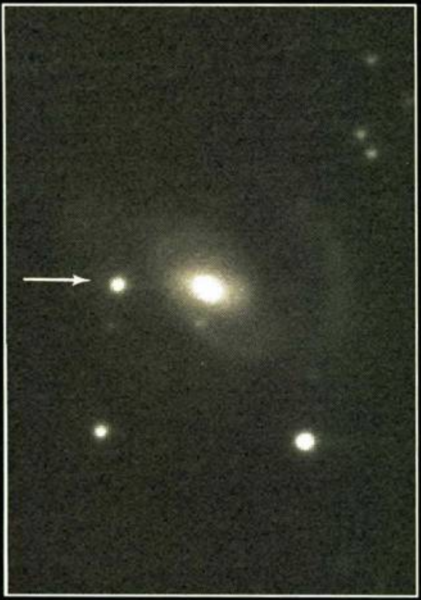
By midnight Bruce Grim and Jachmann had joined Wiggins and the three carted off Jachmann's 9-inch Clark refractor to the site. The sky had cleared overhead. The group arrived, set up, and waited for first contact. They were joined by Joan Carman and Jerry Foote. First contact arrived at 1:08 a.m., but Ganymede's disk appeared unchanged. However, by 1:35 a.m. the group detected that "the right side of Ganymede appeared flattened, dark, and blurry." Boosting the magnification to 520x and waiting until 1:45 removed any skeptical caution. The shadow definitely was visible on Ganymede.

"Not only had the weather cooperated," writes Wiggins, "but the telescope performed beautifully. It was a rare and spectacular event, and thanks to the magazine for alerting us to it."

Astronomy Day Aurora. Members of the Edmonton Centre of the Royal Astronomical Society of Canada enjoyed promoting backyard astronomy on Astronomy Day, held on May 9. But they also received a bonus: a terrifically bright aurora. "It started in the southeast and southwest," reports Alister Ling. "The aurora soon retreated into the north and transformed into a coronal display. For the most part the aurora appeared pale, but some areas became bright green, and some broad spikes became visible near the Moon.

"The aurora seemed to be a rather run-of-the-mill event for skies over Edmonton," says Ling. "But suddenly curtains developed in the northern sky and the most gorgeous lilac colors I've ever seen rippled along the base of the curtains. People began shouting excitedly at the sheer magnificence of the display. Five minutes later, it was back to the typical pale green show that we tend to curse. For Astronomy Day, it was a nice added touch!" □

ASTRONOMY wants to hear about your observations of the sky. Please send reports, sketches, and photographs to David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187.



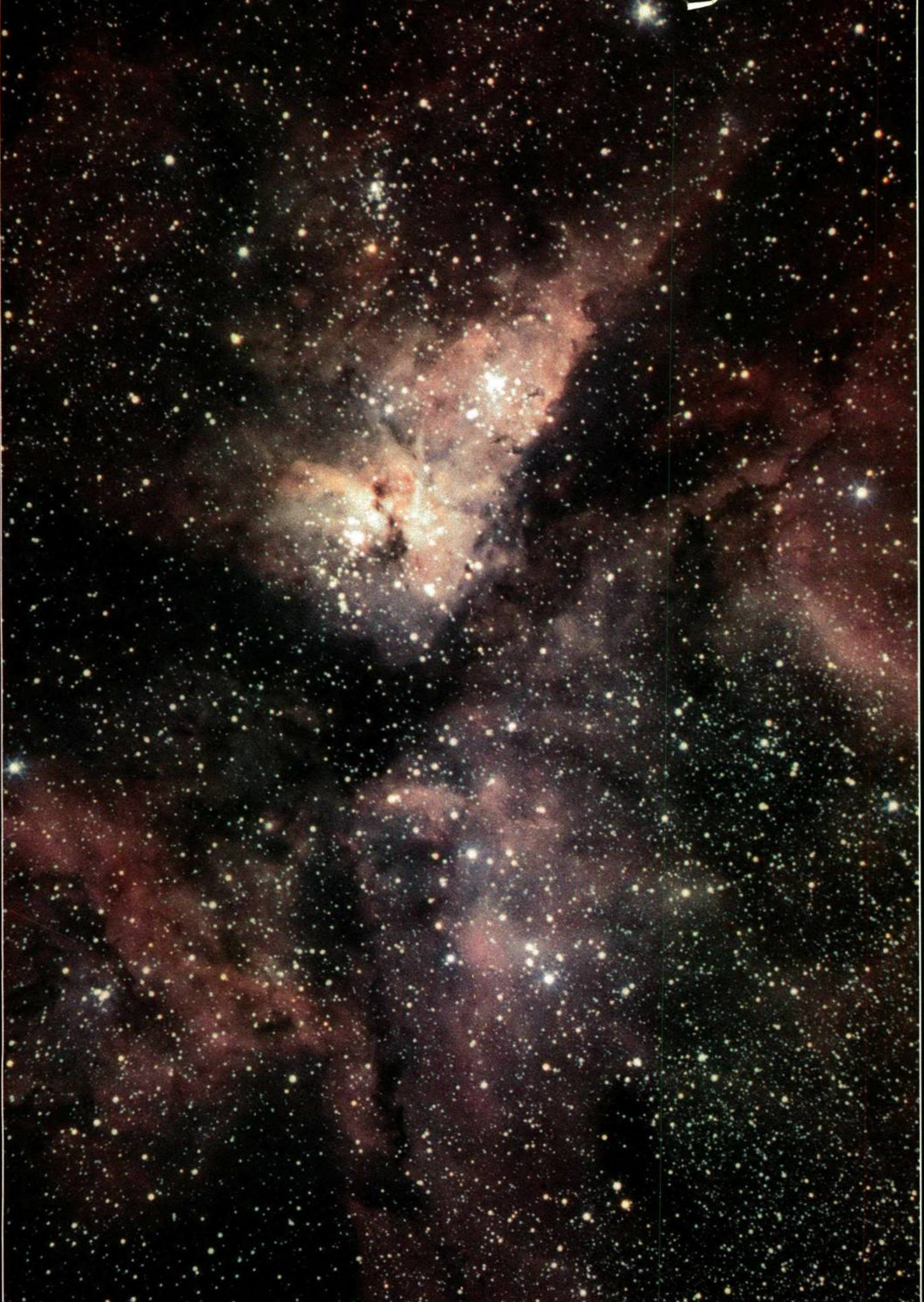
ELEGANT SWIRLS OF NEBULOSITY

One of the prettiest deep-sky objects lies deep in the southern sky. The Eta Carinae Nebula, the brightest emission nebula in the sky, is a naked-eye object. Steve Quirk's photo of the central portion of the Eta Carinae complex (opposite page) wins this month's $100 "Best Astrophoto" award. Quirk used a 12-inch f/4.5 reflector, hypersensitized Ektar 1000 film, and a 20-minute exposure.

Northern Hemisphere astrophotographer Paul Boltwood goes after significantly fainter game. Armed with a 10-inch telescope and a CCD camera, Boltwood successfully recorded the faint galaxy-quasar pair NGC 4319 and Markarian 205 (left; the quasar is marked with an arrow), the faint galaxy chain VV 172 (below left), and the peculiar galaxy NGC 520 (bottom left).

In the area of solar system photography, Finland's Arild Mikalsen captured the November 8, 1991 aurora as it touched the Pleiades star cluster (below).

Planetary astrophotographer Jim Rouse recorded fine detail on Jupiter and the Great Red Spot in his photo made on March 1, 1992 (bottom).



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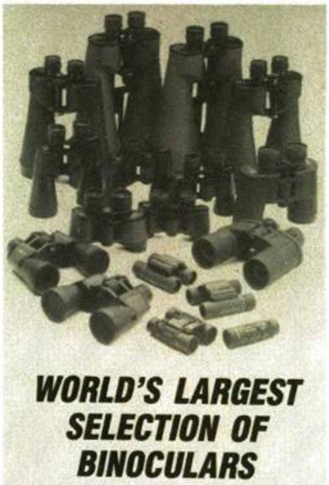

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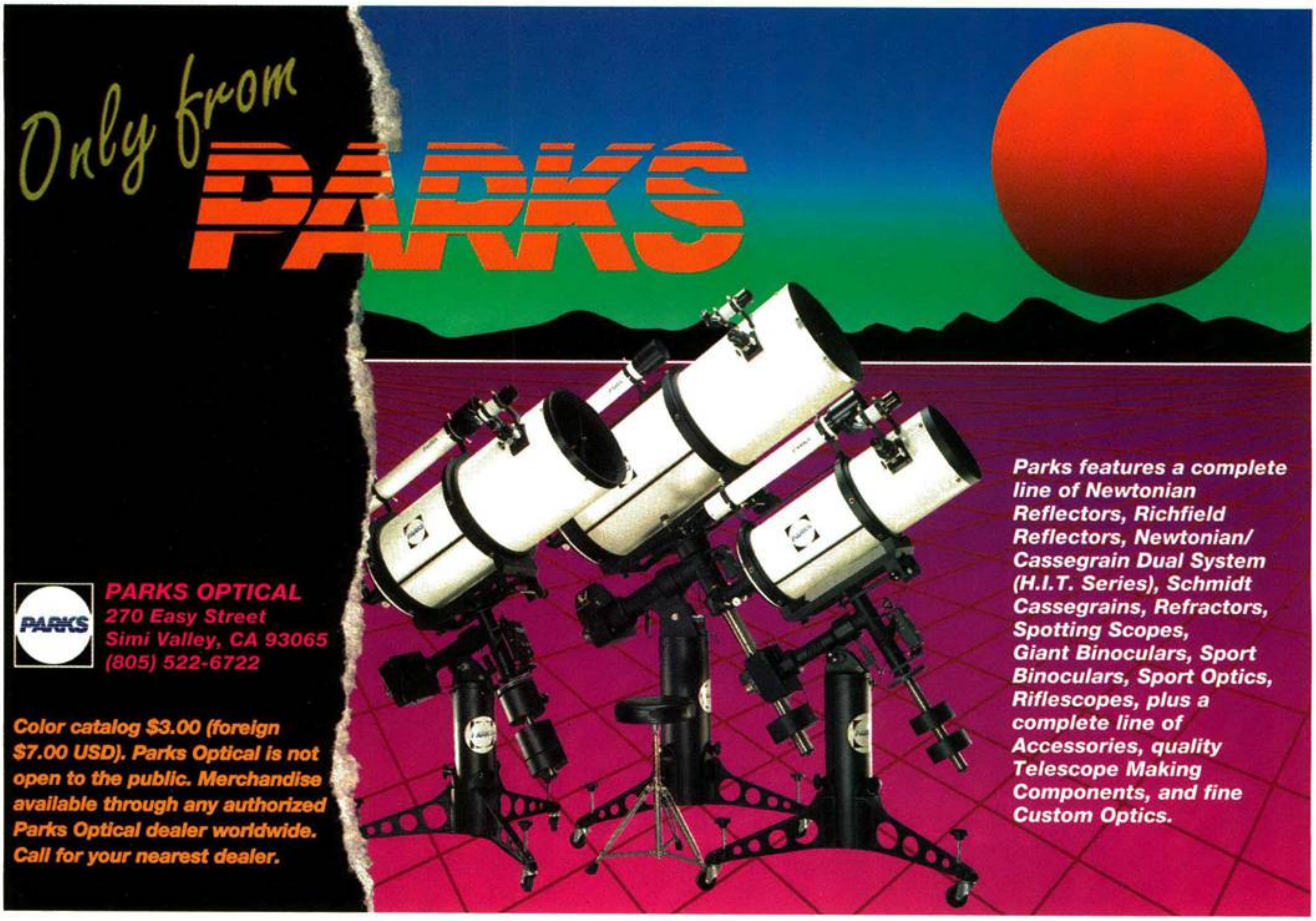

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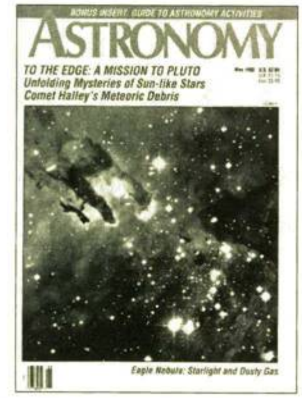
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HOW SCIENCE WORKS

The Science Gap, by Milton A. Rothman, (Prometheus Books, 1992), ISBN 0-87975-710-8, 254 pages, acid-free paper, hardcover, $24.95.

In this easy-to-read volume, Rothman explores both what is "common" science knowledge and the larger philosophical issues behind the problems and questions facing astronomers and physicists. His exploration centers on 16 common statements, such as "Nothing is known for sure," "Nothing exists until it is observed," and "All theories are equal." He uses popular ideas about cosmology, time travel, quantum mechanics, and faster-than-light travel to illustrate his arguments.

In the present era of inflationary universes, dark matter, and high-energy particles with exotic names, the gap between those whose knowledge of nature is based upon scientific observation and the larger numbers whose knowledge depends upon misinformation and misunderstanding is growing. Rothman believes opposition to science is on the rise because more and more people are closing their minds about the nature of the physical universe.

The Science Gap attempts to dislodge many misconceptions about science and how the scientific process works. The chapter on the use of imagination in science is a must-read for anyone who thinks scientists seem bound by conventional theories. The arguments presented in this chapter are especially appropriate in light of the current debate about cosmological models.

Rothman considers himself a realist, someone who believes that things exist independently of your thoughts. He debates the positions of idealists, who believe that things exist only as ideas in the mind. In defending his opinion that modern science is based on realism, he takes on statements made by several noted physicists. I expect every reader will object to one or more of Rothman's statements. But no matter which side of the debate you find yourself on, Rothman's discussion is stimulating and brings life to the discourse about the philosophy of science. — *Dave Bruning*

History of Astronomy

ESO's Early History, by Adriaan Blaauw, (European Southern Observatory, 1991), ISBN 3-923524-40-4, 267 pages, sewn binding, softcover, 25 Deutsche Marks (about $16).

As a former director-general of the European Southern Observatory, Blaauw shares his personal insights into the creation and early days of ESO. The story begins in 1953 with the first idea to form a cooperative partnership of European countries to build and operate a major observatory. Blaauw describes the founding of the observatory, the site survey, and the building of ESO's major telescopes during the 1970s.

Practical Astronomy during the Seventeenth Century, by John T. Kelly, (Garland Publishing, Inc., 1991), ISBN 0-8240-7445-9, 319 pages, acid-free paper, sewn binding, hardcover, $69.

Kelly describes almanacs and almanac makers in England and the American colonies primarily during the 1600s, but with occasional references to almanacs from 1500 to 1800. After the first almanac was printed in the colonies in 1639, thousands of almanacs were sold yearly in the colonies for the purposes of telling time. In this reprint of his 1977 doctoral thesis, Kelly discusses the contents of these early almanacs, the accuracy of the almanacs' predictions, and the teaching of practical astronomy in England and the American colonies.

Space

Blueprint for Space, edited by Frederick I. Ordway, III, and Randy Liebermann, (Smithsonian Institution Press, 1992), ISBN 1-56098-072-9, 224 pages, acid-free paper, hardcover, $60; softcover, $24.95.

Over 160 photographs and illustrations trace the evolution of space travel from the inventions of science fiction writers to science fact provided by Apollo, Viking, and Voyager. Twenty-three authors describe early science fiction, rocketry in the 1920s and 30s, Von Braun's rocket team, Sputnik, Apollo, and visions of the next 25 years in space.

The Rocket Team, by Frederick I. Ordway, III, and Mitchell R. Sharpe, (Aircraft Designs, Inc., 1991), 311 pages, softcover, $48.

This reprint of a 1979 book describes the technological roots of the U.S. space program, starting in the

[continued on page 96]

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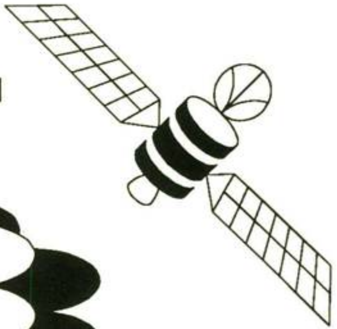

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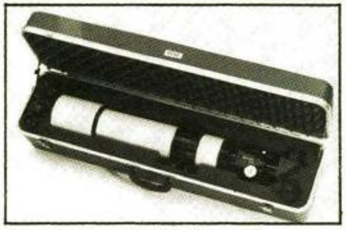

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1920s in Germany. Ordway and Sharpe used declassified documents and interviews with members of Werner von Braun's rocket-design team as the basis for their account of V-1 and V-2 rocket development and the early days of rocketry in Texas, New Mexico, and Alabama. About 30 halftone photos illustrate the book.

The Extraterrestrial Encyclopedia: Our Search for Life in Outer Space, by Joseph A. Angelo, Jr., (Facts on File, Inc., 1991), ISBN 0-8160-2276-3, 240 pages, acid-free paper, hardcover, $40.

The *Extraterrestrial Encyclopedia* describes the important terms and concepts related to space exploration and the search for life in the universe, including entries on Mars Observer, the Uranus and Neptune flybys, Magellan's mapping of Venus, and the Galileo mission to Jupiter. Angelo explains different facets of space travel, such as gravity-assisted orbital maneuvers, and presents many tables, such as the near star encounters predicted for the Pioneer 10 spacecraft.

Comets

1993 Comet Handbook, edited by S. Nakano and D.W.E. Green, (Smithsonian Astrophysical Observatory, 1992), 52 pages, $10 (postpaid). Make checks payable to the International Comet Quarterly and send to Daniel Green, Smithsonian Astrophysical Observatory, 60 Garden St., Cambridge, MA 02138.

Nakano and Green list the positions and orbital elements of 55 long- and short-period comets in this seventh edition of the *International Comet Quarterly's Comet Handbook*. They provide estimated total and nuclear magnitudes, the comet's daily rate of motion, estimated tail length and position angle, and positional information for both the B1950.0 and J2000.0 equinoxes. The comets listed should be observable in 1993 or have a reasonable chance of discovery during the year.

Other Books Received

Neutron Stars: Theory and Observation, edited by Joseph Ventura and David Pines, (Kluwer Academic Publishers, 1991), ISBN 0-7923-1397-6, 592 pages, acid-free paper, hardcover, $146.

Primordial Nucleosynthesis and Evolution of the Early Universe, edited by K. Sato and J. Audouze, (Kluwer Academic Publishers, 1991), ISBN 0-7923-1193-0, 628 pages, hardcover, $129. ☐

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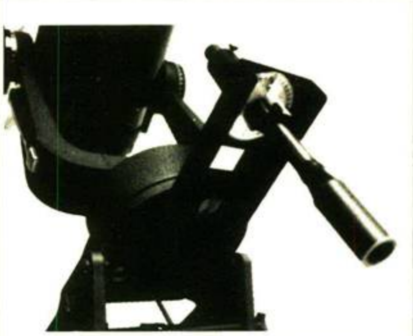

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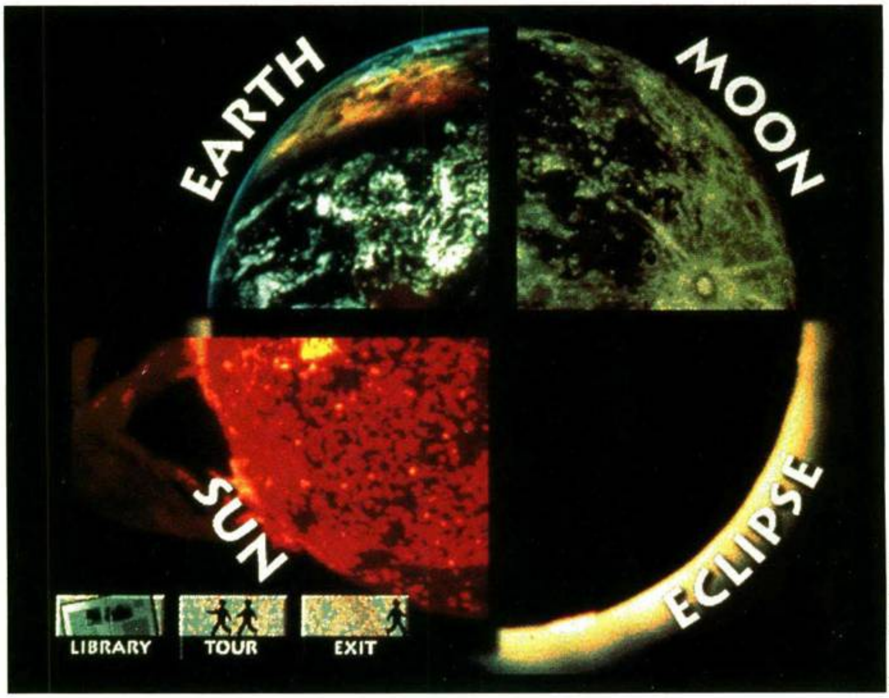

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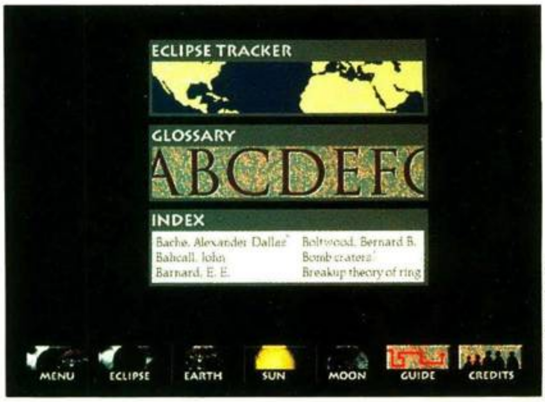

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***The View from Earth**, Time-Life Books, Warner New Media, 3500 W. Olive Avenue, Suite 1050, Burbank, CA 91505. $79.98. Minimum requirements: Macintosh II-series or LC computer, 2 MB of free memory, System 6.0.5, CD-ROM drive. Color display is highly recommended.*

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***The Study of Variable Stars**, Volume II of the "Hands-on" Universe workbook series, Santa Barbara Instrument Group, 1482 East Valley Road, Suite 601, Santa Barbara, CA 93108. Phone (805) 969-1851. $19.95. Requires TS-24, version 2.2 or higher, for Macintosh or PC-XT compatible computers.*

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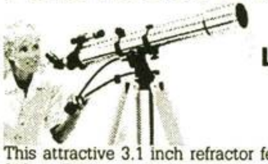

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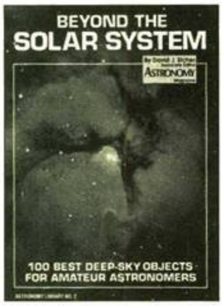

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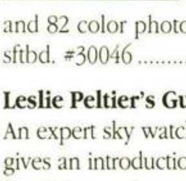

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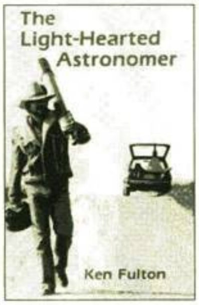

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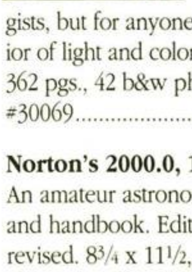

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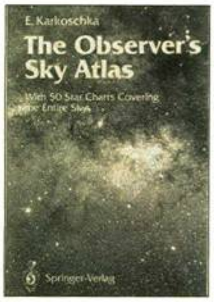
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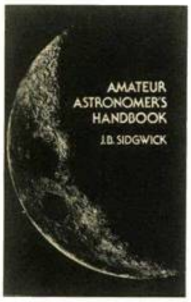
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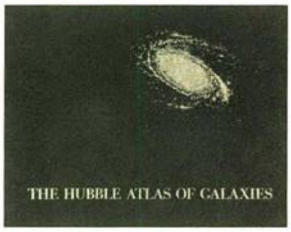
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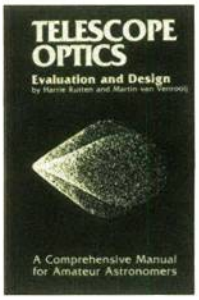
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Enjoy the brightest galaxies—spirals, barred spirals and other peculiar energetic bodies. These vivid, color photographs are from the world's greatest observatories. 6 prints, 11 x 14. #18530..................................**$16.95**

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Identify the stars and constellations, follow hourly, daily and annual progressions, plot the positions of the stars and much more. Just rotate the plastic discs until the hour and date coincide. Lightweight and made of waterproof plastic to go anywhere. $10\frac{1}{2}$" diameter.
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The finest dramatic images of Neptune from the Voyager 2 flyby are presented in this spectacular full-color poster. Also features informative text on Neptune and the flyby. Printed on high-gloss stock. 24 x 36.
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This poster shows the planets and paths of all major space probes. Glows in the dark. Includes a 30 page booklet. 36 x 36.
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Uranus Poster
The sharpest color images of Uranus and its moons from the spectacular Voyager 2 flyby as captured on high-gloss print.
30 x 21. #18527 ....**$6.95**

New Astronomy Products

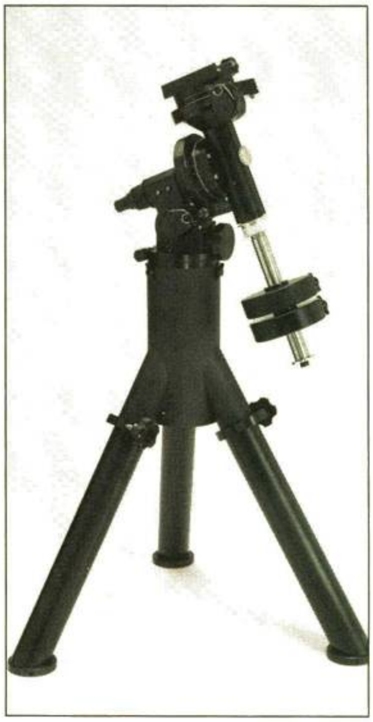
1

New German Equatorial Mount by Losmandy

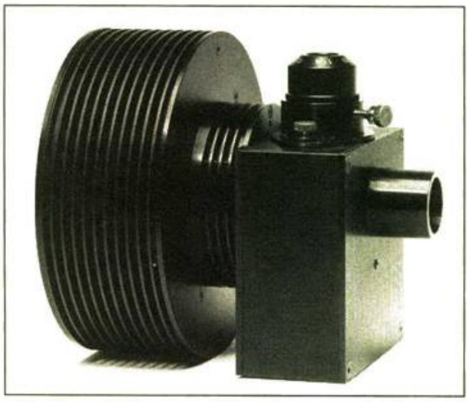
The G-11 mount (right) is made for Celestron International by Scott Losmandy, known for his line of heavy-duty mounts and mounting accessories. The 31-pound equatorial head is capable of carrying telescopes weighing up to 60 pounds. It features a 5.6"-diameter 360-tooth worm gear on each axis, each driven by a 100-ounce-per-inch stepper motor. Other features include an illuminated polar-alignment telescope, fine elevation and azimuth adjustments, a latitude range of 12° to 64°, and a removable mounting bar for attaching a variety of optical tube assemblies. The electronic drive system operates from 12 volts DC and offers 3 guiding speeds, 3 slewing rates, periodic error correction, and programmable declination backlash compensation. The control box also accepts CCD autoguiders.

Celestron also offers its C11 optical tube assembly on the Losmandy mount as a complete package called the CG-11 (far right). The standard fork-mounted Ultima 11 PEC (not shown) is also available but now comes with a heavy-duty wedge and tripod.

Celestron International, 2835 Columbia Street, Torrance, CA 90503, (800) 421-1526, FAX: (310) 212-5835. CG-11 Telescope and Mount: $5,598; G-11 Mount only: $2,798; Ultima 11 PEC fork-mounted telescope with wedge and tripod: $3,650.



2



Color Filter Wheel for CCD Imaging

Santa Barbara Instrument Group (SBIG) has developed a Color Filter Wheel, color balancing software, and a detailed operating manual describing how to do color imaging with a CCD camera. The Color Filter Wheel attaches to the front of SBIG's ST-6 Imaging Camera. It has four filter positions (one each for red, green, and blue filters and a fourth position for an opaque filter for dark frames). A star diagonal position directs the light to an eyepiece positioned at the same focal point as the ST-6, allowing users to locate and focus objects. The ST6COLOR software allows the user to combine images, register them, and balance the color levels for true-color VGA display. It also includes other image-processing functions such as flat-field calibration, sharpening, and smoothing.

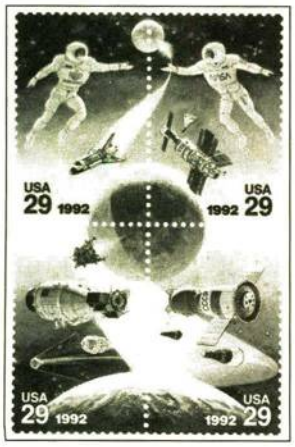
Santa Barbara Instrument Group, 1482 East Valley Road, Suite J601, Santa Barbara, CA 93108, (805) 969-1851. Write for prices, a catalog, and a free demonstration disk of tricolor CCD images.

3

Space Exploration Stamps

The United States Postal Service has introduced a block of four stamps celebrating American and Russian space accomplishments. The stamps are a joint issue between the United States and Russia, with the two countries' stamps differing only in country name and denomination. The stamp artwork is a reproduction of a commissioned painting created by space artists Robert McCall of the United States and Vladimir Beilen of Russia.

United States Postal Service, 475 l'Enfant Plaza SW, Room P108 NBLDG, Washington, DC 20260-3122, (202) 268-6353.

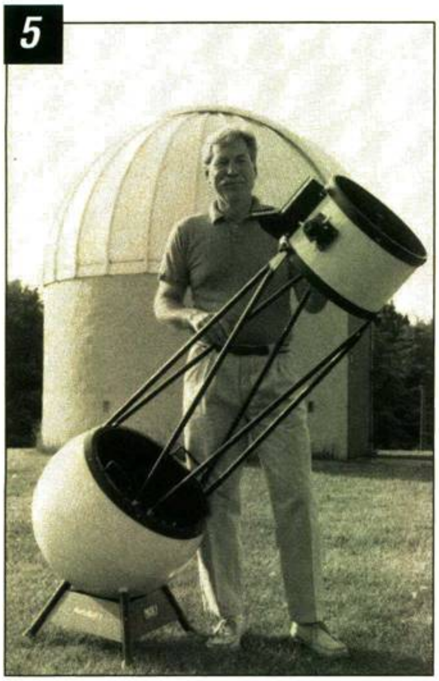


4

Zero-Expansion Ceramic Glass Blanks

Pirate Instruments announces the availability of an affordable ceramic glass with a coefficient of expansion of 0.5×10^{-7}, 65 times more stable thermally than Pyrex. Pirate Instruments offers this glass in many standard diameters (with custom sizes up to four meters available for purchase). Pirate Instruments also offers precision grinding and polishing services.

Pirate Instruments, 28073 Diaz Road, Suite D, Temecula, CA 92590, (714) 694-5876, FAX: (714) 694-5878. Call, write, or FAX for current prices.



5 PortaBall 1 Telescope

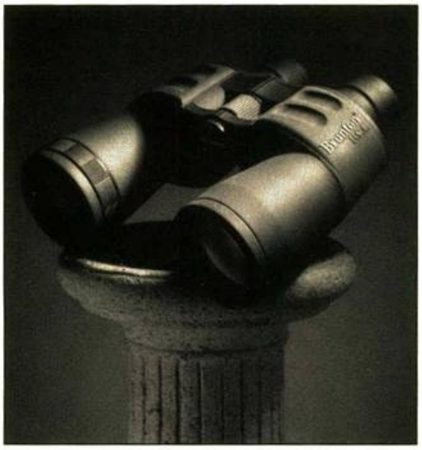
The 12.5" PortaBall 1 uses a 22"-diameter spun-aluminum ball as a large bearing for ultra-smooth movement in all directions. The design also allows the user to rotate the eyepiece easily to any convenient viewing position. In addition, unlike traditional Dobsonians, this telescope moves easily through the zenith. The telescope features diffraction-limited f/5 optics, and comes with a Telrad finder and a choice of either a Novak or AstroSystems focuser. Collimation is fast and accurate. Quick setup requires only one person. When disassembled, the top cage slides into the ball for compact storage and transportation, allowing the telescope to fit into any size car. Total weight of the telescope with optics is 71 pounds.

MAG 1 Instruments, 16342 Coachlight Drive, New Berlin, WI 53151, (414) 785-0926. $2,395. Write for free flyer.

6 Long-Eye-Relief Binoculars from Brunton

The Eterna series of binoculars allows viewing of the full field of view, even when wearing glasses. Special coatings reduce ultraviolet and infrared light while improving transmission over the visible part of the spectrum. The 7x42 model has a 9.4° field of view while the 10x50 version has a 6.3° field. Both models feature gray rubber armoring, a contoured design, a padded Cordura carrying case, and an extra-wide neck strap.

Brunton U.S.A., 620 East Monroe Avenue, Riverton, WY 82501-4997, (307) 856-6559, FAX: (307) 856-1840. 7x42: $280; 10x50: $300.



7 StarDate Radio Show on CD

StarDate, the daily astronomy radio program produced by the McDonald Observatory, is now distributed to radio stations on compact discs. The general public can purchase these disks on a subscription basis. Each CD contains 30 or 31 two-minute programs of sky-watching information and news of astronomical discoveries. A year's subscription includes 12 CDs, each mailed at the end of the broadcast month (for example, CDs of September's programs are mailed at the end of September).

University of Texas at Austin, McDonald Observatory, RLM 15.308, Austin, TX 78712-1090, (512) 471-5285, FAX (512) 471-5060. One-year subscription: $75; individual CDs: $9.95. □

READER'S EXCHANGE

FOR SALE — *THE TREKKER news&views*: Star Trek pictures, contests, fan exchanges, astronomy conventions, and more. Bi-monthly publication, $20 per year. Also *KLINGON RECIPE BOOK*, $8. Write to 1231 Garfield Rd., Havertown, PA 19083.

FOR SALE — Beginner's telescope package: Edmund 3" f/6 reflector with Celestron 18mm ortho eyepiece (25x magnification, 1.9-degree field of view), Edmund *Mag 5 Star Atlas and Sky Guide*, observing aids, and personalized recording forms. $150 including shipping in continental U.S. Contact Spence Blakely, 15 Maize Corn Rd., Portsmouth, RI 02871. Phone (401) 683-4763 evenings.

WANTED — Amateur astronomer, 35 years old, seeks correspondence worldwide, in English or Spanish, with anyone interested in astronomy. Other interests: SETI, chess, computers, and UFOs. Contact Edgar Castro, Apdo. Postal 307 "I," 01907 Guatemala, GUATEMALA.

WANTED — Fifteen-year-old astronomer seeks correspondence with people (preferably between 15 and 20 years old) on any topic, including astronomy, space, pasta, and more. Will respond in Russian, French, or English. Contact Joe Hodes, 6490 Kinsey Pl., St. Louis, MO 63109.

FOR SALE — Complete astrophotography outfit: Olympus OM-1 body, case, Sigma zoom lens, viewfinder cup, shutter cable, gadget bag, tele-extender, and T-ring. $295. Contact M. Mann, 4102 W. Orchid Ln., Phoenix, AZ 85051. Phone (602) 939-8555.

WANTED — Twenty-two-year-old new amateur astronomer interested mainly in planetary science seeks correspondence with amateur/professional astronomers from western U.S. Contact Marc Conza, P.O. Box 1707, Ft. Myers, FL 33902.

FOR SALE — Original, fully detailed scale plan for 10-foot domed or roll-off observatory. $49.95 for either set. Contact John Hicks, Golf Road, P.O. Box 75, Keswick, Ontario L4P 3E1, CANADA. Phone (416) 476-3496.

WANTED — Nineteen-year-old seeks correspondence with young adults in U.S. or Canada who are interested in astronomy. Other interests include SF and horror films, computers and music. Contact Craig Wallington, 37/228 Beauchamp Rd., Matraville, NSW 2036, Sydney, AUSTRALIA.

FOR SALE — ASTRONOMY Magazine, 1974 and 1976-1981 in binders, and September 1982-August 1984 loose. *Sky and Telescope*, 1980-1981 in *S&T* boxes. All $125 plus postage. Contact Dan Brock, P.O. Box 15392, Baton Rouge, LA 70895-5392. Phone (504) 927-6707.

WANTED — Young woman wishes to correspond with science-fiction fans, astronomers and SETI enthusiasts worldwide. Contact Charlotte Kilbane, P.O. Box 505, Henley-on-Klip, 1962, TVL, REPUBLIC OF SOUTH AFRICA.

FOR SALE — Edmund Scientific "AstroScan" 2001 telescope with RKE 28mm and 12mm eyepieces plus 2.5x Barlow and rubber eyecups. Used 4 times. New sells for $534; will sell for $300 including shipping. Contact Mike Gooch, 7320 W. 93rd, Zionsville, IN 46077. Phone (317) 873-3812.

WANTED — Brazilian male, 19 years old, wants place to stay in U.S. for a year or more. Wants to learn about northern skies and U.S. colleges. Contact Harley Rodrigues Soares, Rua Burarama 257, Capitao Eneas 39445, MG, BRAZIL.

WANTED — Nineteen-year-old Brazilian male wants to correspond with people in English, French, German, Spanish, Italian, or Portuguese. Contact Walter Lucio Pinto Ferreira, Rua Nossa Senhora da Guia 282, Capitao Eneas 39445, MG, BRAZIL.

WANTED — Pamphlet, "How to Build a Dobsonian Telescope." Back issues of *TELESCOPE MAKING* Magazine. Contact Michael Torres, 320 E. 167th St. Apt. #11, Bronx, NY 10456-4042. Phone (212) 992-5609.

FOR SALE — Ronchi grating filters, 2x2". $1.50 plus self-addressed, stamped envelope. Contact Dudley B. Wicker, 848 Sherman Ave., Salt Lake City, UT 84105.

FOR SALE — Collection of space memorabilia including rare patches, hardware, and photos. Also *Science News*, 1970 through 1988. Contact Gregg Linebaugh, P.O. Box 604, Glenn Dale, MD 20769.

FOR SALE — Unitron 3" f/16 equatorial refractor. Includes many accessories and cases. Contact Richard Balistreri, 240 Meredith Ln., W. Hempstead, NY 11552. Phone (516) 292-3147 evenings.

WANTED — Spilhaus Space Clock, sold by Edmund in 1960s. Also other clocks with astronomical functions. Contact Michael Maiman, 2970 Hallmark Dr., Belmont, CA 94002. Phone (415) 591-3370.

WANTED — Correspondence with anyone interested in astronomy, cosmology, particle physics, other sciences, and agnosticism. Contact Poh-Meng Liow, Apt. Blk. 58 Chai Chee Drive, #10-126, Singapore 1646, REPUBLIC OF SINGAPORE.

WANTED — Autographed pictures of astronauts, from Mercury program to present. Also autographed pictures of cosmonauts. Send list including prices. Contact Jaymie Haist, 1016 Rudy Ave., Mattoon, IL 61938. Phone (217) 235-0035.

FOR SALE — Bogen 3021 steel tripod with #3029 tripod head, $90 or best offer. Also Parks 1.55" secondary mirror with holder. $40. Prices include shipping. Contact Mark Burger, 3401 MacVicar, Topeka, KS 66611. Phone (913) 266-7980.

WANTED — Male, 38 years old, seeks correspondence with female interested in astronomy, electronics, or computers. Contact Perry Marchant, 764 E. Twain Ave. Suite #14A, Las Vegas, NV 89108. Phone (702) 796-1460.

WANTED — Halley's Comet souvenirs. Also space-related pins, patches, or coins. Send description to Doug Smith, 385 Allison Rd., Murfreesboro, TN 37130.

WANTED — Contact with amateur astronomers living in or near Johnson and surrounding counties of Kentucky. Also information about area astronomy clubs. Contact Kevin C. Redden, 208 E. Dorton Blvd., Crosscreek Subdivision, Staffordsville, KY 41256.

FOR SALE — ASTRONOMY Magazine, 1990 and 1991. $18 one year, $35 both. Postage included. Contact Gary A. Libertore, 5103 Hamilton Ave., Baltimore, MD 21206.

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With Carry Case **All for only** **289⁹⁵**

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Carry Case for 2045-S	**44.95**

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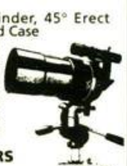

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Meetings & Events

September 12
StarConn '92, Wesleyan University, Middletown, Connecticut. Contact: Astronomical Society of Greater Hartford, P. O. Box 2271, Hartford, CT 06145-2271.

September 18-19
Twin Lakes Star Party, Golden Pond Observatory, Kentucky. Sponsored by the West Kentucky Amateur Astronomy Club. Contact: Jim Boren, Land between the Lakes, Golden Pond, KY 42211. Phone: (615) 232-7405 (days), (615) 232-6820 (evenings).

September 18-20
Astrofest, Camp Shaw-Waw-Nas-See, near Kankakee, Illinois. Sponsored by the Chicago Astronomical Society. Contact: Astrofest, P. O. Box 596, Tinley Park, IL 60477. Phone: Alan Birkner at (708) 966-6214.

September 18-21
Meeting of European (and International) Planetary and Cometary Observers, Violau, Germany. Contact: Wolfgang Meyer, Martinstrasse 1, D-(W)1000 Berlin 41, Germany.

September 25-26
Hidden Hollow '92, Mansfield, Ohio. Sponsored by the Richland Astronomical Society. Contact: Keith Moore, P. O. Box 1118, Mansfield, OH 44901-9998. Phone: (419) 755-7796 (days), (419) 468-3542 (evenings).

September 25-26
NIAG Fest '92, Camp Crosley, near North Webster, Indiana. Contact: Michiana Astronomical Society, P. O. Box 262, South Bend, IN 46624-0262.

September 25-26
2nd Annual FRASC Star Party, Pawnee National Grasslands, Colorado. Sponsored by the Longmont Astronomical Society. Contact: Alan Poppenhagen, 2035 Sumac Street, Longmont, CO 80501. Phone: (303) 651-9030.

September 25-26
6th Annual Dark Sky Observing Party, Cathedral Gorge State Park, Panaca, Nevada. Sponsored by the Las Vegas Astronomical Society. Contact: Jim Mellor, Great Western Hotels, 401 South Casino Center Boulevard, Las Vegas, NV 89101. Phone: (800) 634-6635.

September 25-26
10th Annual Northern Virginia Telescope Meet, C. M. Crockett Park, Calverton, Virginia. Contact: Bob L'Hommedieu, 4415 Eastwood Court, Fairfax, VA 22032. Phone: (703) 978-0946.

September 25-27
2nd Annual Connecticut Star Party, Colebrook, Connecticut. Sponsored by the Astronomical Society of New Haven. Contact: Astronomical Society of New Haven, P. O. Box 3005, New Haven, CT 06515.

September 26, October 24
8th Annual Blue Ridge Parkway Regional Stargaze, Julian Price Park, near Blowing Rock, North Carolina. Sponsored by the Catawba Valley Astronomy Club. Contact: Greg Kirby, Route 3, Box 472, Granite Falls, NC 28630. Phone: (704) 396-7656.

October 2-4
Stella-Della-Valley V, Camp Onas, Ottsville, Pennsylvania. Sponsored by the Bucks-Mont Astronomical Association. Contact: Ed Radomsky at (215) 822-8312 or Bob Post at (215) 322-8384.

October 16-18
Antique Telescope Convention and Show, U. S. Naval Observatory, Washington, D.C. Sponsored by the Antique Telescope Society. Contact: Walt Breyer, 30 Green Valley Road, Wallingford, PA 19086.

October 16-18
8th Annual Midwest Space Development Conference, Worthington, Ohio. Contact: Studio A, Inc., P. O. Box 261592, Columbus, OH 43226. Phone: (614) 548-7743.

October 17
Gathering of the Clans, Vancouver, British Columbia. Sponsored by the Vancouver Centre of the Royal Astronomical Society of Canada. Contact: Vancouver Centre, c/o H. R. MacMillan Planetarium/Gordon Southam Observatory, 1100 Chestnut Street, Vancouver, BC V6J 3J9. Phone: (604) 736-4431.

October 17
Saturn Watch '92, Holcomb Observatory, Indianapolis, Indiana. Sponsored by the Indiana Astronomical Society. Contact: Philip May, 2 Wilson Drive, Mooresville, IN 46158. Phone: (317) 831-3009 (days), (317) 831-8387 (evenings).

October 17
Starfest '92, Bays Mountain Park, Tennessee. Sponsored by the Bays Mountain Amateur Astronomers. Contact: Bays Mountain Amateur Astronomers, 853 Bays Mountain Park Road, Kingsport, TN 37660. Phone: Charles Ferguson at (615) 229-9447.

October 19-25
9th Annual Okie-Tex Star Party, Prude Ranch, near Fort Davis, Texas. Sponsored by the Oklahoma City Astronomy Club. Contact: Oklahoma City Astronomy Club, P. O. Box 21221, Oklahoma City, OK 73156. Phone: Clive or Beryl Cadle at (405) 789-3472.

October 22-25
Astro Scopers Starfest, Chiefland, Florida. Contact: Astro Scopers, c/o Sparky, Route 1 Box 302-C, Chiefland, FL 32626. Phone: (904) 493-4359.

October 22-25
Georgia Star Party, Future Farmers of America campground, near Covington, Georgia. Sponsored by the Astronomical Society of the Atlantic. Contact: Jim Rouse, 1307 Candlelight Lane, Snellville, GA 30278. Phone: (404) 979-9475.

October 22-25
10th Annual Deep South Regional Stargaze, Percy Quinn State Park, near McComb, Mississippi. Sponsored by the Ponchartrain Astronomy Society. Contact: Barry Simon, 820 Emerald Street, New Orleans, LA 70124. Phone: (504) 283-7592.

October 23-25
14th Annual Astronomy Jamboree, Southold, New York. Sponsored by the Custer Institute. Contact: Charles Cardona at (516) 298-4227 or Barbara Lebkuecher at (516) 722-3850.

October 23-25
7th Annual Astronomy Weekend, Blackwater Falls State Park, Davis, West Virginia. Sponsored by the West Virginia Division of Tourism and Parks and the Kanawha Valley Astronomical Society. Contact: Pat Northeimer, Blackwater Falls State Park, P. O. Box 490, Davis, WV 26260. Phone: (800) 225-5982 or (304) 925-1143. □

Please submit announcements at least four months before the date of the meeting or event. When you write to organizations listed in Meetings and Events, include a self-addressed, legal-sized envelope with your request for information.

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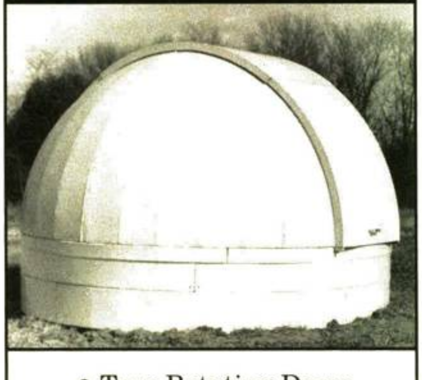

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Readings & Resources

Mars Observer: Return to the Red Planet (page 28)

Return to the Red Planet, by Eric Burgess, (Columbia University Press, 1990). A survey of past and future exploration of Mars.

Mars Beckons, by John Noble Wilford, (Vintage Books, 1990). A similar review of Mars missions.

Where Has Pluto's Family Gone? (page 40)

"Do Brown Dwarfs Really Exist?," by Deborah Byrd, ASTRONOMY, April 1989. Describes how brown dwarfs may form and astronomers' searches for these elusive objects.

"Lost and Found: Pulsar Planets," by David Bruning, ASTRONOMY, June 1992. The story of Wolszczan and Frail's discovery of the first planets detected outside of our solar system and the retraction by Andrew Lyne of his group's discovery of another pulsar planet.

Hop into Deep-sky Observing (page 60)

Beyond the Solar System: 100 Best Deep-Sky Objects for Amateur Astronomers, by David J. Eicher, (Kalmbach Publishing Co., 1992). Describes the 100 best deep-sky objects for observers with small telescopes and explains how to find them.

Hunting down the Helix (page 63)

Burnham's Celestial Handbook, by Robert Burnham, Jr., (Dover Publications, 1978). Includes exhaustive information on the Helix and other objects in Aquarius.

Getting the Exposure Right (page 78)

The Backyard Astronomer's Guide, by Terence Dickinson and Alan Dyer, (Camden House, 1991). Contains extensive chapters on astrophotography.

Astrophotography for the Amateur, by Michael Covington, (Cambridge University Press, 1991). A recently revised introduction to all the basic techniques.

"Staging a Moon Shot," by Mark Coco, ASTRONOMY, August 1992. A primer on photographing the Moon and the exposures it requires.

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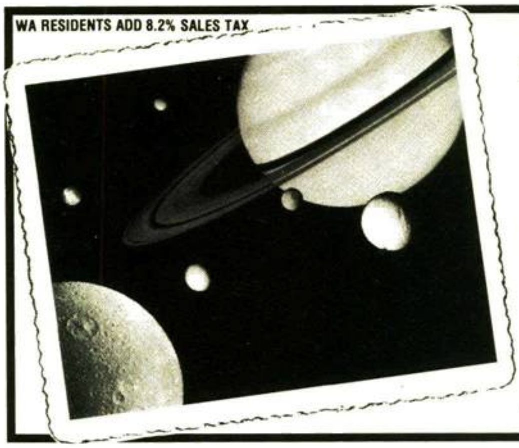

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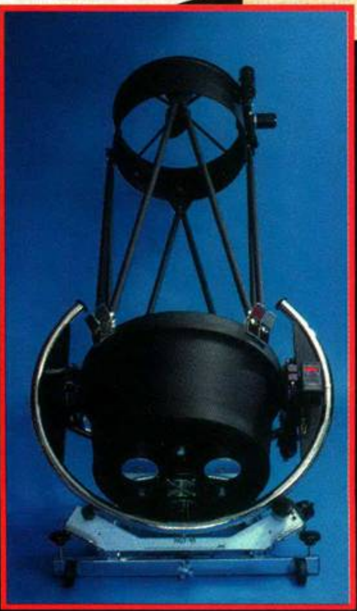

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